TRANSACTIONS OF THE

American Foundrymen's Association

Proceedings of the

Thirty-second Annual Meeting

PHILADELPHIA, PENNSYLVANIA

May 14 to 18, 1928

VOLUME XXXVI

Edited by ROBERT E. KENNEDY

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Summary of the Proceedings of the Thirty-second Annual Meeting

Philadelphia, Pa., May 14 to 18, 1928

The thirty-second annual convention of the American Foundrymen's Association was held at Philadelphia, Pa., in connection with the twenty-first annual exhibit of foundry equipment and supplies. The attendance was approximately 7,000 men, which attendance was the largest in the history of the Association. The Exhibits were shown in the Philadelphia Commercial Museum. The Exhibits in point of space were the third largest grouping, being exceeded only by the exhibits of 1920 at Columbus and 1926 at Detroit. The floor space of the Philadelphia exhibits covered 75,238 square feet.

The 1928 convention made the fourth A. F. A. convention held in Philadelphia, where the Association was organized in 1896.

Attendance at the technical sessions was unusually large and the cupola operation course, an innovation, a series of four discussion periods, attracted an attendance of about 400 at each meeting, indicating an unusual interest in this type of convention activity.

Another innovation, the first annual exhibitors' dinner of the A. F. A. was attended by about 300 and was addressed by S. W. Utley, as president of the A. F. A. Short talks were made by George Pickop, H. Cole Estep and W. H. McFadden.

As appropriate in connection with the fourth convention in Philadelphia, the birthplace of the A. F. A., a dinner was given to those who had attended the first A. F. A. meeting. S. T. Johnston, president-elect, presided. Mr. Johnston, who has attended every meeting of the Association since its formation, introduced the speakers, amongst whom were Howard Evans, John A. Penton, Walter Wood, W. H. McFadden and Dr. C. B. Connelley.

Technical Exhibits

The technical exhibits included (1) a demonstration of sand testing and control equipment put on by the Committee on Molding Sand Research, (2) an exhibit of patterns and castings made by foundry apprentices and entered in the national contest sponsored by the A. F. A., and (3) an exhibit of castings of malleable iron, gray iron and steel.

Castings Exhibit

The object of this last exhibit was to show to the visitors possibilities in engineering properties of castings. The steel castings exhibit was organized by the Steel Founders' Society of America. The malleable exhibit by the Malleable Iron Research Institute and the gray iron exhibit was organized by a committee formed by the A. F. A. Great interest was shown in this undertaking, 18 steel foundries, 12 malleable foundries and 27 gray iron foundries furnished castings.

Apprentice Exhibit

The apprentice exhibit had castings and patterns made by the apprentices of the following firms:

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Engineering Co., Philadelphia, Pa.
Bettendorf Co., Bettendorf, Iowa.
Brown and Sharpe Mfg. Co., Providence, R. I.
Bucyrus-Erie., So. Milwaukee, Wis.
Builders Iron Foundry, Providence, R. I.
Cresson-Morris Co., Philadelphia, Pa.
John Deere Harvester Co., Moline, Ill.
Filer and Stowell Co., Milwaukee, Wis.
French and Hecht Co., Davenport, Iowa.
General Electric Co., Lynn, Mass.
General Electric Co., Schenectady, N. Y.
Harnischfeger Corp., Milwaukee, Wis.
Milwaukee Pattern and Mfg. Co., Milwaukee, Wis.
Moline Implement Co., Moline, Ill.
Olney Foundry Co., Philadelphia, Pa.
Pettibone-Mulliken Co., Chicago, Ill.
Pusey and Jones Corp., Wilmington, Dela.
Sivyer Steel Casting Co., Milwaukee, Wis.
Westinghouse Electric & Mfg. Co., Philadelphia, Pa.
Williams White and Co., Moline, Ill.

Technical Sessions

The morning technical sessions were held at the Hotel Bellevue-Stratford, the afternoon meetings at the Commercial Museum. For the second year, the opening session of the convention has been devoted to the presentation of reports of chairmen of technical committees. These reports present in a brief form the activities covered by the committees during the year. Reports this year were presented for the following committees:

Industrial Relations, Chairman, H. Cole Estep.
Apprentice Training, Chairman, H. A. Frommelt.
Foundry Costs, Chairman, A. E. Hageboeck.
Molding Sand Research, Chairman, B. D. Fuller.
Heat Treatment of Ferrous Metals, Chairman, A. W. Lorenz.
Corrosion of Metals, Chairman, H. Y. Carson.
Foundry Refractories, Chairman, James R. Allan.
Gray Iron Castings, Chairman, J. L. Jones.
Steel Castings, Chairman, A. H. Jameson.

In addition to the business session, there were held 20 technical meetings, including the two round table luncheon gatherings for those interested in malleable and non-ferrous metals and the four period shop operation course.

The shop operation course on cupola practice was initiated as an experiment to meet the needs of the practical shop man. Their purpose is not to provide discussion on the newer metallurgical or engineering developments, but to provide an opportunity to discuss the fundamentals of foundry practice.

The 46 papers and 16 reports were grouped as follows:

Non-Ferrous	5	Costs	3
Steel	11	Malleable Iron	5
Cast Iron	11	Management	4
Materials Handling	4	Coke	1
Sand	10	Apprentice Training	8

The cupola shop operation course sessions were held at 4:00 P. M. on each of the first four days of the convention, the sessions being of two hours' duration. The leaders were:

First session—Dr. Richard Moldenke.
Second session—E. J. Lowry.
Third session—David McLain.
Fourth session—H. W. Dietert.
Details of the regularly scheduled technical sessions follow:

Session No. 1—Opening Meeting—Annual Business Session.
Tuesday, May 15, 10:00 A. M.

President S. W. Utley presided, and at this time presented his annual address which will be found on page xxxi.

Following the delivery of his annual address, President Utley called upon the chairmen of the various committees to present reports of their committee activities.

H. Cole Estep presented his report as Chairman of the Committee on International Relations.

H. C. ESTEP: Mr. Chairman, Mr. Secretary and gentlemen: It is one of the ambitions of the Committee on International Relations to bring the foundry industry of the United States to a stop for about a month, about a year hence, because we hope that such enthusiasm will be aroused in reference to the Third International Foundryman's Congress, which will be held in London in June, next year, that so many foundrymen will leave the country on that particular occasion, that of necessity the industry must be brought to a standstill during that period, or perhaps profit immensely by their absence. Seriously, though, gentlemen, you knew a movement was started, some eight years ago, by a group of men from various countries interested in the welfare of the foundry industry of the world in general. It was realized that foundrymen on the other side of the water had problems, and had discovered methods which they could bring to us, which would be greatly to our advantage to know more about, and we, in our turn perhaps could contribute somethirg to them. In addition to that, there is no doubt, as Mr. Utley, our President, pointed out in his address yesterday noon, that business men the world over have to take a larger responsibility in political affairs; and I do not think it is too much to say that the two international gatherings of foundrymen we have already held, one in Paris in 1923 and the second in Detroit in 1926, were of real, tangible value in bringing about a better understanding between the peoples of the world, which will have assuredly a beneficial political effect; in other words, we are doing something so entirely beyond and above our own industry in interesting ourselves in these international congresses. I have a very brief statement which I will present to you, the purpose of it being mainly to give you an outline of the program which our host for this particular congress next year,

the Institute of British Foundrymen, has already carefully outlined for our benefit.

Mr. Estep then read the outline of the itinerary for the American foundrymen who are to attend the 1929 International Foundry Congress.

In the absence of Chairman H. A. Frommelt of the Apprentice Training Committee, C. J. Freund read the report for this body.

C. J. FREUND: The Apprentice Training Committee during the past year followed closely the paths of its past endeavors to assist in a solution of the trade training problem in the foundry industry in this country. These activities were largely of a promotional nature. This has consisted in an effort to convince the industry separately and as a unit of the feasibility and practicability of training for the essential trades that constitute this basic industry.

The point of attack during the past twelve months has largely centered around the local foundrymen's associations. It has been recognized that the vast majority of our foundries are entirely too small to establish apprentice training on an individual basis. Results must come through the co-operative efforts launched by the local foundrymen's or manufacturing groups which include the foundry branch.

The program for the Philadelphia Convention is a further attempt to solve the problem through this method of attack. The outstanding community training plans are here presented in the hope that they will furnish other industrial communities with the inspiration and methods necessary to a successful solution of the problem of skill in the individual foundry organization.

The committee now proposed to launch out in another direction. The propaganda work of the past must be continued; but already we are facing problems of administration of training programs, where such are in effect, which a group such as the A. F. A. apprentice training committee can assist in solving. The coming year will therefore see an attempt by your committee of some research work along these lines.

A. E. Hageboeck, Chairman of the Committee on Foundry Costs reviewed the work of his committee, outlining the character of the program which this committee had planned for its session of the convention.

B. D. Fuller, Chairman of the Committee on Molding Sand Research, was next called upon. His report follows:

B. D. Fuller: The work of the Committee on Sand Research has progressed satisfactorily this past year through the activities of the various sub-committees. The sub-committee on tests has prepared a revision of the 1924 pamphlet giving the standard and tentative tests of foundry sands. Approval for this revision will be requested at the sand session on Thursday of this week. This new pamphlet will have, in addition to tests previously approved, tests for strengths by tensile method, by shear method, and by compression method, no one strength method being found satisfactory for all conditions. A tentative refractoriness test has also been included. Tests being developed are for mold hardness, mold permeability, and durability or life. The grading sub-committee is continuing its work of sand properties classifications for the purpose of developing a means for expressing the comparative value of these properties. The geologic surveys of molding sand resources of the foundry sand producing states is completed and the final test results will be published following this meeting. Some twenty states have been covered in this work and in addition to the survey of results being published in the A. F. A. Transactions, the states of New York, Illinois, Pennsylvania, and Kentucky have used these test data in their own state survey reports and Virginia, Wisconsin, Maryland, Michigan and Tennessee are now preparing their state publications for printing. Future committee activities will be directed toward simplification of test methods, development of adequate tests and properties for which no proper tests are at present available and further classification of properties to permit of the use of uniform specifications.

A. W. Lorenz as Chairman of the Committee on Heat Treatment of Ferrous Metals stated that:

"The Committee on Heat Treatment of Ferrous Metals was primarily organized to co-operate with A.S.T.M. A-4 Sub-Committee on Heat Treatment of Iron and Steel Castings. This Committee is at present inactive, although it is possible that the coming year may see some developments that will warrant our attention."

Secretary Hoyt read the reports of H. Bornstein and H. Y. Carson, which had been submitted to President Utley. Their reports are as follows:

Report of Committee of A. F. A. Representatives on Metals Committee Advisory to Bureau of Standards

A meeting of the Metallurgical Advisory Committee to the Bureau of Standards was held on May 11th and 12th at the Bureau of Standards, Washington, D. C. The A. F. A. had several representatives at this meeting.

The purpose of the meeting was to give information relative to the work of the Metallurgical Division during the past year and to discuss plans for work for the coming year.

Mr. J. B. Deisher as the A. F. A. representative on Malleable Iron Castings, presented a list of problems of the industry which should be given consideration.

The A. F. A. supported the work which was done during the past year on the pyrometry of molten cast iron and the results of this work have been published in the form of a paper before the present A. F. A. Convention.

The Bureau is ready to go ahead on investigations of machinability and wear testing of cast iron, providing funds can be secured for that purpose. This work would be of extreme importance and deserves the financial support of the A. F. A.

Respectfully submitted,

H. BORNSTEIN, *A. F. A. Representative on Ferrous Metals Committee Advisory to the Bureau of Standards.*

REPORT OF COMMITTEE ON CORROSION OF FERROUS METALS:

The foundry industry has the greatest opportunity in its history for service to mankind. Our studies of corrosion continue to reveal important data. Soil corrosion alone is annually destroying more than half a billion dollars. The destroyed material is for the most part not foundry products and therein lies the opportunity for a better development of our castings. We may therefore take new inspiration on our development of processes for making better gray iron, better malleable, and better cast steel to meet these severe corrosive conditions, thereby saving to mankind untold waste that will otherwise accrue.

Respectfully submitted,

H. Y. CARSON, *Chairman, Committee on Corrosion of Ferrous Metals.*

J. R. Allan was called upon to present his report as the A. F. A. representative on the Joint Committee on Foundry Refractories and as the Chairman of the A. F. A. Committee on Refractories.

J. R. ALLAN: The American Foundrymen's Association's Committee on Refractories represents the foundry consumers of refractories and functions in all the work and activities of the Joint Committee on Foundry Refractories.

Through this representation on the Joint Committee, we are making surveys of each branch of the foundry industry in order to obtain working information that will aid in standardizing the shapes and provide specifications and tests for the various grades of refractories.

During this past season the recommendations for standardization of sizes of refractories for the malleable industry have been accepted by the Division of Simplified Practice, Department of Commerce, Washington. With this in effect, the variety of shapes for the industry has been reduced from more than 188 to 24, a reduction of at least 164 shapes.

Active study of the problem concerning refractories with regard to the gray iron, electric cast steel, sleeves, stoppers and nozzles, and nonferrous industries are under way. This coming season should see further evidence of work satisfactorily completed and also new work started.

Your committee wishes to thank the A. F. A. membership for the fine co-operation and assistance given the activities of the Joint Committee and asks for the continued support of the important work under way.

The Chairman of the Committee on Gray Iron Castings, Jesse L. Jones, then presented his report.

J. L. Jones: During the year 1927-28 the Committee has done work in the following fields:

1. Research,
2. Bibliography of Cast Iron,
3. Synthetic Cast Iron,
4. International Test Bar.

1. Research work in co-operation with the Bureau of Standards. The results of this work are available to the members of the A. F. A. in two papers presented at the present convention, viz.—The Temperature Measurements of Molten Cast Iron, by H. T. Wensel and W. F. Roeser, Bureau of Standards, Washington, D. C., and Heat Losses from a 75-Ton Hot Metal Car, by W. F. Roeser, Bureau of Standards, Washington, D. C.

Work on the fluidity of molten cast iron is under way.

2. Bibliography on Cast Iron. Under the direction of John W. Bolton, a bibliography of about 1500 references to articles on cast iron has been published by the A. F. A.

3. Synthetic Cast Iron. Several members of the Committee have run all steel tests during the year and the results may be had by any one interested.

4. International Test Bar. Dr. Richard Moldenke represented the Committee at the Barcelona, Spain, meeting in April, 1928, and did considerable to keep close interest in this question.

A. H. Jameson then read the report of the Committee on Steel Castings. This report, which was signed by all the members of the committee, was also later read before the Session on Steel held on Wednesday, May 16th.

A. H. JAMESON: Last June your Committee appealed to you for support in a controversy regarding certain points in a specification proposed by a Committee of the American Society for Testing Materials for Carbon Steel Castings for Valves, Flanges and Fittings for High Temperature Service. You responded in gratifying numbers and we are glad to report that at the General Meeting of the American Society for Testing Materials in French Lick last June the objectionable changes were withdrawn and the Specifications left as they had been, and as we wished them to be, the points at issue being referred back to the proper committee for further consideration and recommendations.

Since then, while a special committee was being formed to consider these controversial points, an attempt was made, informally, to reach a basis of compromise, but owing to the development of certain opposition, the attempt did not then succeed. So at meetings of the American Society for Testing Materials Committee held in March of this year, it was voted to refer these points back to the proper committees for further consideration, and the matter stands just where it did a year ago. We hope that a final settlement may be reached this coming year, one that will be acceptable to both sides. The points at issue will be made the subject of discussion at the Steel Founding session tomorrow morning.

To us, your committee, the most gratifying features of the entire matter have been the evidence of interest you have shown, and the enthusiastic support you have accorded us.

Major R. A. Bull then presented his report as the A. F. A. representative on the Joint Committee on Determining the Influence of Phosphorus and Sulphur in Steel Castings.

R. A. BULL: Since the last A. F. A. convention, material for determining the influence of phosphorus in steel castings was made at the plant of the Atlantic Steel Casting Company, Chester, Pa., under the observation of and according to procedures outlined by the Joint Committee on the Investigation of Phosphorus and Sulphur in Steel. This required the production of eight acid open hearth heats, each having a desired composition differing from that of any other heat in the series.

Following a specially prepared program, the test material was given heat treatments at the U. S. Bureau of Standards, some of it being normalized, some being normalized and drawn, and some being annealed with a furnace cooling. No material is to be tested in the condition as cast.

The test material has been chemically analyzed and forwarded to the Naval Engineering Experiment Station at Annapolis and to the Watertown Arsenal for machining and testing, to ascertain values indicating resistance to fatigue, compression, tension, torsion and impact; and to ascertain hardness. All tests are to be conducted at room temperatures. The results of the tests will probably be announced by the time of the next A. F. A. convention.

The A. F. A. received special contributions amounting to $1010.00 for financing these tests. Of this amount it was necessary to expend only $742.61. This sum, together with a very substantial amount generously contributed by the Steel Founders' Society of America, provided for all the items of expense not borne by the three Government institutions that have been co-operating in this investigation, which has now been carried on for nine years by eleven organizations of national character. All told, 110 steel casting companies have shared in defraying the expense of making these tests. Thus have steel foundrymen demonstrated their disposition to co-operate for obtaining accurate information that will advance the industry.

This entire matter is covered by a detailed report to be presented Wednesday, May 16, 2 P. M. at session No. 12.

Following the reading of these reports President Utley called upon John Shaw of Southsea, England, for a few remarks. Mr. Shaw in response stated that the British foundrymen were looking forward with a great deal of pleasure to the visit of the American foundrymen to England at the time of the Third International Foundry Congress in 1929. He emphasized the need for international co-operation in fostering the interests of the foundry industry.

President Utley next announced the appointment of the Committee on Resolutions. The Committee named was:

Past President, A. E. Howell, Chairman,
E. F. Cone,
N. K. B. Patch.

Secretary Hoyt read the report of the committee on nomination of officers and directors. This report nominated the following:

For President, to serve for one year:

S. T. JOHNSTON, Vice-President of the S. Obermayer Company, and Vice-President of the National Engineering Company, both of Chicago, Ill.

For Vice-President, to serve for one year:

FRED ERB, President, Erb-Joyce Foundry Company, Detroit, Mich.

For Directors, to serve three-year terms each:

S. W. UTLEY, Vice-President, Detroit Steel Casting Company, Detroit, Mich.

L. W. OLSON, Works Manager, Ohio Brass Company, Mansfield, Ohio.

B. H. JOHNSON, Works Manager, Cresson-Morris Company, Philadelphia, Pa.

PETER J. KRENTZ, Vice-President and Works Manager, Buffalo Foundry & Machine Company, Buffalo, N. Y.

C. E. HOYT, Executive Secretary, A. F. A., Chicago, Ill.

Secretary Hoyt, after reading the report, moved that the candidates whose names were read be declared elected to the respective offices for which they were nominated.

The motion was seconded and carried and the nominees were declared duly elected.

Secretary Hoyt then reported that at a meeting of the Board of Directors held on May 13th, the Board voted unanimously to recommend the election to honorary membership of President S. W. Utley.

Past President Alfred E. Howell moved that S. W. Utley be elected an honorary member of the American Foundrymen's Association.

The motion was seconded and carried, the members arising and applauding. President Utley expressed his appreciation of the honor the Association had conferred upon him.

The meeting was then adjourned to reconvene at 4:00 P. M. Thursday, May 17th.

Adjourned Business Meeting
4 P. M. Thursday, May 17

President Utley presided and as the first order of business he called for the report of the Committee on Resolutions. Chairman Howell submitted the report which consists of two sections and is given as follows:

REPORT OF COMMITTEE ON RESOLUTIONS:

Mr. President and Members of the American Foundrymen's Association, in Convention Assembled:

Your Committee, appointed by President Utley, begs to report:

When it was first announced that the 32nd Annual Convention of the Foundrymen's Association was to be held in Philadelphia, the "Workshop of the World" the "City of Homes," we knew that there was a world of capability, for knowledge, for industry, for joy, spread round about us—meant for us—inviting us.

And we have found it so. While not first in population or of aggregated wealth, nevertheless Philadelphia is the source of many "firsts"—the first Bank in America, the first Trust Company, the first Savings Fund Society, the first Life Insurance Company, the first Fire Insurance Company, the first Building and Loan Association, the first Title Insurance Company, and the birthplace of the American Foundrymen's Association, all in the interest of our country and the welfare of human society.

So, when we come to Philadelphia, we think reverently of Benjamin Franklin, of Robert Morris, of Stephen Girard, as well as of all those patriots who wrought so mightily in the formation of the Constitution of our great Country.

It is not appropriate now to lengthen our reflections on Philadelphia and her just fame nor to comment on her "active and comfortable ways." Our present duty is plain, to attempt an expression of our thoughts on this, the fourth occasion of her great hospitality to our Association.

Philadelphia has initiative, wisdom, skill and virtue. Initiative is demonstrated in the number and variety of her "firsts"; Wisdom in knowing what to do; Skill in being able to do it; and Virtue in doing it.

Mayor Mackey, the Chamber of Commerce and the officers of various Boards have been most gracious and active in our behalf. The general Chairman of the Philadelphia Committee, Mr. G. H. Clamer, one of our Ex-Presidents, had already endeared himself to members of the Association by his many unselfish services. Now by his tact and perspicacity he has made himself doubly dear by heading the numerous Committees who have made our sojourn so delightful and profitable. To the Chairman of each of these Committees

Mr. C. F. Hopkins
Mr. Laird U. Park
Mr. B. H. Johnson
Mr. J. A. Davies
Mr. Walter L. Kalbach
Mr. Earl S. Sparks
Mr. Frederick M. Devlin
Mr. Ralph Belleville
Mr. T. H. Addie
Mr. Walter Wood
Mr. Howard Evans

and through them to the individual members of each, we wish to record our lively appreciation.

We wish also to acknowledge our indebtedness to the many great industries which have made wide their portals in hospitality to visiting foundrymen. Modern business, scientifically conducted, scorns secrecy, and in this have shown their largeness of vision. We wish also to include your Hotel Association which has outdone itself for our comfort.

The ladies of our party have been provided with most delightful and lavish hospitalities, and in their behalf (although they can usually be depended upon to speak for themselves,) we wish to record profound appreciation.

"Appreciation"—one of the greatest words, is wholly spiritual. To the spiritual ear, Philadelphia and its environs, presents a scene which makes music, at once virile with action and rural with gentle solace, discoursing pleasant reflections on the high destiny of mankind.

In leaving Philadelphia, it is with the hope we shall clasp you again as you clasped us in our infancy, with life and affection forever old yet new, changed not in kind but in degree, and this the 32nd degree.

Respectfully submitted,

Alfred E. Howell
N. B. K. Patch
E. F. Cone

Committee.

To the President and Members of the American Foundrymen's Association, in Convention Assembled:

Your Committee on Resolutions begs to report—

This, the 32nd Annual Convention of the American Foundrymen's Association marks the high point in our history. The fourth meeting in Philadelphia, we have returned to our birthplace. Many events have transpired in these thirty-two years. The progress of the world in scientific knowledge and its application to the various arts and industries is so astonishing that not a man of us but congratulates himself on living in this era and thinks with regret that his father and grandfather could not behold present day marvels. These it would be beyond the duty assigned this Committee to attempt to enumerate.

But we are concerned with some expression, even though inadequate, of the advances of our own industry which have contributed so vitally to all other progress. We are concerned to express the esteem in which we hold our President, our Board of Directors, the numerous authors of those excellent and outstanding scientific and technical papers presented at our various sessions—our Exhibitors, our Executive Secretary, C. E.

Hoyt, our Technical Secretary, R. E. Kennedy, and Mr. Hoyt's most efficient staff.

Those who have functioned within our Association, your Committee feels should be separately dealt with, but to so deal would entail a tax on your time, though not on your spirit, which spirit flows, as thought does, with unmeasured speed.

President Utley, himself, is a theme which could be modulated from the dynamic and definite intoning of a great bell to the quiet and complex symphony of reflection, introspection, observation and inspiration—evoking aspirations and convictions.

President Stuart Wells Utley accepted the presidency at a time when it was known that no exhibit nor great numerical attendance could be expected, as at the experimental meeting at Chicago where the scientific and technical considerations were alone featured. His courage and self-effacement and unselfish devotion, we recognize, and it is now with the greatest satisfaction that we record our gratification that his regime was continued so that he has been our leader and presiding officer on this great occasion, when not only the basic, scientific purposes of our meetings have been subserved, but by a wonderful spirit of co-operation our exhibitors have added a spectacle, never exceeded, of all those appliances and materials so necessary in our industry. These were made visible and tangible for the thousands who have attended.

Only by the greatest wisdom and tact has this great co-ordination of energy been achieved, and we ascribe this success to our President, S. W. Utley, and to our Secretary, C. E. Hoyt, who have attracted to themselves this great concert of action, of their Board, the various and numerous Committees, and Authors and Exhibitors, and Staff.

So, to say what we would like about either or both and all, would necessitate extension of specific praise and esteem to so many, that your Committee would be chastened for prolixity. In fine, let us say that in full and profound appreciation of each—in the language of Charles Dickens, through Mr. Micawber, "Among the eyes elevated toward you from the various sections of this great country, in esteem and appreciation, shall ever be, while they have light and life, the eyes appertaining to" the grateful members of the American Foundrymen's Association.

Respectfully submitted

Alfred E. Howell
N. K. B. Patch
E. F. Cone

Committee.

Past President B. D. Fuller moved the adoption of these resolutions. The motion was seconded and unanimously adopted.

President Utley read the resolutions submitted by the Apprentice Training Committee. These read as follows:

WHEREAS: The work of training young men for the foundry industry and for industry in general is seriously handicapped by a lack of information as to the number of young men and boys who are employed as apprentices in the various industries, and

WHEREAS: The biennial census of manufacture of the United States constitutes an excellent medium, already existing, for the gathering of such information, therefore be it

RESOLVED: That the American Foundrymen's Association, through its Board of Directors, petition the United States Government to include statistics in its biennial census of manufactures regarding the total number of young men being trained in the various industries by formal or indentured apprenticeship and the proportion which this number bears to the number of skilled mechanics.

A motion was passed that the above resolution be approved and referred to the Board of Directors for further action.

There being no further business to come before this meeting a motion to adjourn was approved.

Session No. 2—Non-Ferrous Metals
Tuesday, May 15, 11:00 A. M.

Chairman, G. H. Clamer, Past President of the A. F. A.

Papers presented and discussed were as follows:

SCIENCE IN THE FOUNDRY, by E. F. Hess, Ohio Injector Company, Wadsworth, Ohio.

FURNACE REFRACTORIES FOR BRASS FOUNDRIES, by H. M. St. John, Detroit Lubricator Company, Detroit, Mich.

THE EFFECT OF MELTING AND POURING CONDITIONS UPON THE QUALITY OF No. 12 ALUMINUM ALLOYS, by T. W. Bossert, Aluminum Company of America, New Kensington, Pa.

RISERS, THEIR NEED AND FEEDING, by R. R. Clarke, General Electric Company, Erie, Pa.

THE EFFECTS OF LEAD ON THE PROPERTIES OF A COMPLEX BRASS, by O. W. Ellis, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Session No. 3—Steel Metallurgy
Tuesday, May 15, 11:00 A. M.

Chairman, W. J. Corbett, Steel Founders Society of America, Pittsburgh, Pa.

The following papers and committee report were presented and discussed:

GENERAL CHARACTERISTICS OF ALLOY STEEL CASTINGS, by J. W. Frank, Chicago Steel Foundry Company, Chicago, Ill.

MANGANESE STEEL, by H. P. Evans, and A. F. Burtt, Pettibone-Mulliken Company, Chicago, Ill.

A MODERN PLANT FOR THE HEAT TREATMENT OF MISCELLANEOUS STEEL CASTINGS, by A. W. Lorenz, Bucyrus-Erie Company, Milwaukee, Wis.

RESEARCH LABORATORY OF THE AMERACAN STEEL FOUNDRIES, by W. C. Hamilton, American Steel Foundries, Indiana Harbor, Ind.

REPORT OF COMMITTEE ON HEAT TREATMENT OF FERROUS CASTINGS.

Session No. 4—Cupola Developments
Tuesday, May 15, 11:00 A. M.

Chairman R. F. Harrington, Hunt-Spiller Manufacturing Corporation, Boston, Mass.

Papers presented and discussed were:

THEORY OF CUPOLA OPERATION IN RELATION TO PRACTICE, by R. B. Schaal, Roberts and Manders Stove Company, Hatboro, Pa.

AUTOMATIC BLAST GATE CONTROL FOR CUPOLA MELTING, by H. V. Crawford, General Electric Company, Schenectady, N. Y.

CUPOLA REFRACTORIES, by C. E. Bales, Ironton Fire Brick Company, Ironton, Ohio.

Session No. 5—Foundry Costs
Tuesday, May 15, 2:30 P. M.

Chairman A. E. Hageboeck, Frank Foundries Corporation, Moline, Ill.

At this session two papers were read and one report presented. The papers were:

THE SCHEDULE FALLACY, by J. J. Ewens, The George H. Smith Steel Casting Company, Milwaukee, Wis.

NECESSITY FOR CREATING A CASTINGS CONSCIOUSNESS, by A. F. Jensen, The Hanna Engineering Company, Chicago, Ill. (Presented on behalf of the Foundry Equipment Manufacturers' Association.)

REPORT OF THE COMMITTEE ON FOUNDRY COSTS, presented by W. J. Corbett, Chairman of Sub-Committee on Standard Divisions of Foundry Cost Accounts. Included in this report were the following recommendations:

1. Recognition by the A. F. A. of the Uniform Cost System of the Steel Founder's Society of America and recommendation for its use in all steel foundries.
2. Recognition by the A. F. A. of the Uniform Cost System of the Malleable Iron Research Institute and recommendation of its use in all malleable foundries.
3. That the A. F. A. encourage the Gray Iron Institute to develop a uniform cost system for gray iron foundries.
4. That the A. F. A. encourage the organization of a representative group of non-ferrous foundries for the purpose of developing a uniform cost system for non-ferrous foundries.

The recommendations of the report were approved on motion and referred to the Board of Directors for action.

Second Session—Cupola Operation Course
Tuesday, May 15, 4:00 P. M.

Chairman, E. J. Lowry, Detroit, Mich.

The discussion of this session was on the subject, Cupola Construction Details. No papers were read, the entire meeting being given over to discussion.

Session No. 6—Steel Founding
Wednesday, May 16, 10:00 A. M.

Chairman, J. Fletcher Harper, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

The schedule of papers and reports follows:

ECONOMIES IN OXY-ACETYLENE CUTTING FOR RISER REMOVING, by G. O. Carter, Linde Air Products Company, New York, N. Y.

VARIABLES IN STEEL FOUNDRY PRACTICE, by F. A. Melmoth, Thos. Firth and Sons, Ltd., Sheffield, England. Annual Exchange Paper of the Institute of British Foundrymen.

REPORT OF COMMITTEE ON STEEL CASTINGS.

The I. B. F. exchange paper in the absence of the author was presented by George Batty, who was formerly associated with the author in his work. The report of the Committee on Steel Castings was presented by Chairman A. H. Jameson. Major R. A. Bull, a member of the Committee presented a minority report. Following a discussion of the reports the following resolution was presented by A. H. Jameson:

CONCERNING PROPOSED A. S. T. M. SPECIFICATION A-95—ALLOY STEEL CASTINGS FOR HIGH TEMPERATURE SERVICE—TO BE REFERRED TO THE A. S. T. M.

RESOLVED: That in the opinion of those present, changes proposed at the informal conference in Cleveland, participated in by Messrs. Bull, White, Spring, and Warwick, as a basis of settlement of the much discussed process and chemical limits clauses in A. S. T. M. Specification A-95-26T are not satisfactory.

That the process clause proposed is not acceptable due to its discrimination against two accepted processes without supporting evidence.

That they are also opposed in principle to the inclusion of chemical limits other than for phosphorus and sulphur in specifications where physical limits are specified.

On being seconded, the resolution was approved by a vote of 14 for approval and two opposed. The resolution was referred to the A. F. A. Board for action.

Session No. 7—Cast Iron
Wednesday, May 16, 10:00 A. M.

Chairman, J. W. Bolton, Lunkenheimer Company, Cincinnati, Ohio.

Papers presented and discussed were:

Some Recent Developments in Cupola Metal, by J. D. Miller, Cresson-Morris Company, Philadelphia, Pa.

Influences of Carbon and Silicon Variations in Cast Iron, by D. G. Anderson and G. R. Bessmer, Western Electric Company, Chicago, Ill.

Temperature Measurements of Molten Cast Iron, by H. T. Wensel and W. F. Roeser, U. S. Bureau of Standards, Washington, D. C.

Test Bar for Testing the Hardness of Cast Iron with Medium and High Silicon Contents, by M. Dudouet, Ecole Superieure de Fonderie, Paris, France. Annual Exchange Paper of the French Foundry Technical Association.

Heat Losses From a 75-Ton Hot Metal Car, by W. F. Roeser, U. S. Bureau of Standards, Washington, D. C.

In the absence of the author the paper by M. Dudouet was read in abstract by W. Rother of the Buffalo Foundry and Machine Company.

Session No. 8—Malleable Iron Founding
Wednesday, May 16, 10:00 A. M.

Chairman, F. M. Robbins, Ross-Meehan Foundries, Chattanooga, Tenn.

The five papers presented at this session were:

Reducing Scrap in the Malleable Foundry, by R. A. Greene, Ohio Brass Company, Mansfield, Ohio.

An Incentive Bonus Plan for Molders Based on Scrap Control, by R. J. Teetor, The Cadillac Malleable Iron Company. Cadillac, Mich.

Effects of Various Elements on Malleable Cast Iron, by L. E. Gilmore, Crane Company, Chicago, Ill.

Oxidation Phenomena During Annealing of Malleable Cast Iron, by H. A. Schwartz, National Malleable and Steel Casting Company, Cleveland, Ohio.

The Need for Research in the Foundry, by E. E. Griest, Chicago Railway Equipment Company, Chicago, Ill.

The paper by Mr. Gilmore was read by title.

Session No. 9—Brass Founding
Wednesday, May 16, 12:30 P. M.

Chairman, N. K. B. Patch, Lumen Bearing Company, Buffalo, N. Y.

This session was in the nature of an informal round table meeting following a luncheon gathering. No papers were presented, the chairman calling on various ones among those present to open discussion on topics of general interest. No report of the discussion was made.

Session No. 10—Foundry Management
Wednesday, May 16, 2:00 P. M.

Chairman H. Cole Estep, Penton Publishing Company, Cleveland, Ohio.

The papers scheduled for this meeting were:

BASIC PRINCIPLES OF MANAGEMENT IN THE FOUNDRY, by J. D. Towne, Dayton, Ohio.

STABILIZING LABOR AND CUTTING COSTS, by A. D. Lynch, Ohio Brass Company, Mansfield, Ohio.

WHAT DOES THE BUYER EXPECT FOR HIS MONEY? by J. A. Marks, Packard Motor Car Company, Detroit, Mich.

A CONTRIBUTION TO THE TRAINING OF LABOR AND THE PERSONNEL OF A FOUNDRY, by A. Soupart, Director of the State Vocational Museum and of the Industrial and Vocational School, Morlanwetz, Mariemont, Belgium. Annual Exchange Paper of the Belgium Foundry Technical Association.

In the absence of the author the paper by A. Soupart was read by title.

Session No. 11—Foundry Coke
Wednesday, May 16, 2:00 P. M.

Chairman, A. J. Tuscany, Ohio State Foundrymen's Association, Cleveland, Ohio.

The session was a conference on foundry coke specifications. The one paper for this meeting was prepared as a review of the present status of foundry coke specifications and was:

General Status of Foundry Coke Specifications, by W. A. Selvig, Experiment Station, U. S. Bureau of Mines, and Secretary of the A. S. T. M. Committee on Coke Specifications.

Session No. 12—Steel Founding
Wednesday, May 16, 2:00 P. M.

Chairman W. J. Corbett, Steel Founder's Society of America, Pittsburgh, Pa.

The papers and report presented at this session were as follows:

Reducing New Sand Consumption in a Steel Foundry, by H. A. Mason, Gould Coupler Company, Depew, N. Y.

Interdependence of Operating and Sales Departments in the Success of a Foundry, by K. V. Wheeler, Lebanon, Steel Foundry, Lebanon, Pa.

Report of A. F. A. Representative on Joint Committee on Investigation of Effect of Phosphorus and Sulphur in Steel.

The report was presented by Major R. A. Bull, the A. F. A. representative on the Joint Committee.

Third Session—Cupola Operation Course
Wednesday, May 16, 4:00 P. M.

Chairman, David McLain. The subject discussed at this session was Cupola Charging Practice.

Session No. 13—Apprentice Training
Thursday, May 17, 10:00 A. M.

Chairman E. S. Sparks, Metal Manufacturers Association of Philadelphia, Philadelphia, Pa.

The discussion of this session was centered around reports of the foundry apprentice training situations in various industrial centers of this country. The reports were as follows:

Philadelphia Co-Operative Apprenticeship, by C. F. Bauder, Director, Department of Industrial Arts, Philadelphia Public Schools.

APPRENTICESHIP IN THE DETROIT DISTRICT, by W. J. Hebard, Apprentice Consultant, International Correspondence Schools, Detroit, Mich.

EAST CHICAGO COMMUNITY TRAINING PROGRAM, by H. R. Packard, Secretary East Chicago Chamber of Commerce, East Chicago, Ind.

FOUNDRY APPRENTICESHIP IN PITTSBURGH, by C. D. Carey, President, Pittsburgh Foundrymen's Association, Pittsburgh, Pa.

THE MILWAUKEE DISTRICT APPRENTICE SITUATION, by C. J. Freund, Falk Corporation, Milwaukee, Wis.

FOUNDRY APPRENTICESHIP IN OAKLAND, CALIFORNIA, by H. L. Martin, Secretary, East Bay Foundrymen's Association, Oakland, Calif.

APPRENTICESHIP IN THE QUAD CITIES, by S. M. Brah, District Supervisor, Moline and Davenport District, Moline, Ill.

HARVEY COMMUNITY APPRENTICESHIP, by W. B. Keast, District Apprentice Supervisor, Harvey, Ill.

The reports on the Philadelphia, Pittsburgh, Milwaukee and Detroit districts were reviewed by C. F. Bauder, of the Philadelphia Public Schools. The reports on the other districts were reviewed by F. A. Lorenz, of the American Steel Foundries. Following the reviews the meeting was given over to general discussion.

Session No. 14—Cast Iron Metallurgy
Thursday, May 17, 10:00 A. M.

Chairman, H. W. Gillett, Division of Metallurgy, Bureau of Standards, Washington, D. C.

Two papers and one committee report were presented and discussed. These were:

THEORY OR PRACTICE IN THE GRAY IRON FOUNDRY, by John Shaw, Southsea, England.

RESEARCH PROBLEMS OF THE GRAY IRON FOUNDRY, by J. W. Bolton, The Lunkenheimer Company, Cincinnati, Ohio.

REPORT OF COMMITTEE OF GRAY IRON.

Session No. 15—Malleable Founding
Thursday, May 15, 12:30 P. M.

Chairman, F. L. Wolf, Ohio Brass Company, Mansfield, Ohio.

This meeting was in the nature of an informal round table discussion, following a luncheon gathering. No papers were presented, the chairman calling on various members present to open the discussion on certain phases of shop practice as related to the malleable foundry. No report of the proceedings was made.

Session No. 16—Sand Control
Thursday, May 17, 2:00 P. M.

Chairman, B. D. Fuller, Past President A. F. A.

The schedule of papers and reports was as given below:

SAND CONSERVATION AND CONTROL IN A GRAY IRON JOBBING SHOP, by T. F. Kiley, Brown & Sharpe Manufacturing Company, Providence, R. I.

TESTING MOLDING SANDS FOR DURABILITY, by M. A. Blakey, International Harvester Company, Milwaukee, Wis.

SURFACE CONDITION OF CASTINGS AS AFFECTED BY CORE SAND MIXTURES, by H. L. Campbell, University of Michigan, Ann Arbor, Mich.

SAND CONTROL IN A LIGHT CASTING SHOP, by W. G. Reichert, Singer Manufacturing Company, Elizabethport, N. J.

A COMPRESSION TEST OF HIGH PRECISION—THE COLLOID NATURE OF NATURAL BOND—THE EFFECT OF HEATING OF THE BOND, by C. C. DeWitt, Michigan College of Mining and Technology, Houghton, Mich., and G. G. Brown, University of Michigan, Ann Arbor, Mich.

REPORTS OF COMMITTEES.

The report of the Sub-Committee on Conservation and Reclamation of Foundry Sands was presented by the Committee's Chairman, R. F. Harrington, Hunt-Spiller Manufacturing Corporation, Boston, Mass.

The report of the Sub-Committee on Grading was presented by Chairman A. A. Grubb, Ohio Brass Company, Mansfield, Ohio.

Dr. H. Ries, Cornell University and Chairman of the Sub-Committee on Tests, presented the report for his committee.

As the report of the Sub-Committee on Tests contained recommendations for standards and tentative standards, a motion to refer this report to the Board of Directors was approved. The other reports were accepted as progress reports.

Fourth Session—Cupola Operation Course
Thursday, May 17, 4:00 P. M.

Chairman, H. W. Dietert, Detroit, Mich.

The subject discussed at this session was cupola improvements. No reporter's record of this discussion was permitted.

Session No. 17—Materials Handling
Friday, May 18, 10:00 A. M.

Chairman L. L. Anthes, Past President A. F. A.

The four papers presented at this session were as follows:

MATERIALS HANDLING AND ITS RELATIONSHIP TO BUILDING PLANS, by E. F. Scott, Austin Company, Cleveland, Ohio.

DETERMINING RETURNS FROM MATERIALS HANDLING EQUIPMENT, by J. J. Hartley, The Link Belt Company, Chicago, Ill.

WHAT MATERIALS HANDLING EQUIPMENT CAN DO FOR THE JOBBING FOUNDRY, by W. B. Marshall, The Chain Belt Company, Milwaukee, Wis.

HOW TO DETERMINE WHEN MATERIALS HANDLING EQUIPMENT SHOULD BE INSTALLED, by H. J. Dorus and C. S. Schroeder, Yale and Towne Manufacturing Company, Stamford, Conn.

Annual Address

By the President, Stuart Wells Utley

Opening Session, Thirty-Second Annual Convention, Philadelphia, Pa.

Daniel Webster in his reply to Senator Hayne, that monumental speech which crystallized the thoughts of men in the indissoluble nature of the Union, and made his name immortal, commenced by saying:

"When the mariner has been tossed for many days in thick weather, and on an unknown sea, he naturally avails himself of the first pause in the storm, the earliest glance of the sun, to take his latitude, and ascertain how far the elements have driven him from his true course. Let us imitate this prudence, and, before we float farther on the waves of this debate, refer to the point from which we departed, that we may at least be able to conjecture where we now are. I ask for the reading of the resolution before the Senate."

In these complicated industrial times it is not unwise to pause from time to time, to forget the details of daily operations, and to consider the larger aspects of our work that we may the more clearly see the objects for which we strive.

At the conclusion of a year and a half as President of this Association it seems to me that certain conditions make it wise that I set down my own judgment as to some of the functions of this organization, in the hope that it may be of some benefit to those who follow me; that it may enable them to start off where I am finishing.

The A. F. A. and Conditions of the Foundry Industry

Many times during the past year we have been told that the foundry industry is in a bad way, and that the Association should do something about it. The gray iron man complains

that he is being robbed of work which is going into malleable iron; the malleable man that his customers are buying steel or stampings; the steel man that he is losing work through the use of welded parts or drop forgings—all feel that ruinous competition is threatening the stability of their business; each feels, quite naturally, that his interests should be protected by the Association of which he is a member.

This Association covers an exceedingly wide range of business activities. It numbers among its members foundries producing gray iron, malleable iron, steel and non-ferrous metals, as well as manufacturers of all kinds of foundry equipment. Each of these branches includes companies manufacturing castings which it fabricates and sells as part of a finished article; companies manufacturing a very limited number of special castings either for their own consumption, or for sale to a limited number of customers and companies doing a general jobbing business, making any sort of a casting and selling it to any customer.

In each there are mammoth companies with entirely adequate capital, and little companies with whom the meeting of each pay roll is real agony. In each division are companies who are both manufacturers and buyers; who manufacture one kind of casting, say, gray iron, and purchase others, say, malleable and steel. There is little in common between these various foundries except the fact that they are all making castings from molten metal, and that they all find their own line over-expanded with competition increasingly keen. It is safe to say that there is no single problem of the business or economic world which does not have to be met at some time by one or all of our members.

Activities of Association Necessarily Limited

Should our Association then assume the responsibility of solving all the problems of our industry, which is equivalent to solving all the economic problems of industrial society? Is it humanly possible that any one organization can accomplish such a task? Will we best serve the interests of our members by "messing" all over the field, or by concentrating on some partic-

ular part of it, and by endeavoring to secure a better solution for those particular questions?

There are many lines of endeavor in which the interests of all our groups are fairly identical; there are some in which the interests of competing groups are sharply antagonistic. We must agree that anything which improves the quality of the product of a foundry or a group of foundries making that product of greater use to the human race, is beneficial in the long run to the entire industry, even though it be temporarily detrimental to the welfare of those members who refuse to change old methods in the light of new knowledge. But we must not engage in any activity which seeks to increase the business, or the interests of, or the prosperity of any one of the groups *at the expense of any of the rest of them.* So far as possible we must serve the interests of all jointly, if we are to retain their interest and their co-operation.

Association Devoted to Technical Advancement of Foundry Industry

We are, primarily, a technical Association engaged in studying and improving the product of our industry by taking some of the "guess" and uncertainty out of foundry operations; we are not a trade association concerned with commercial considerations, with merchandising problems, with questions of prices, and with problems of competition. We recognize the gravity of these problems, but it is my judgment after giving the matter long and careful consideration that our membership structure is not so constituted, nor are we so organized that we can assume the responsibility for trying to settle these problems, and, unless we are willing to assume such responsibility, we have no right to make a gesture at their solution in the hope of favorably impressing some of our members. We co-operate in the most friendly manner with the existing trade associations, and engineering societies—The Steel Founders' Society of America; The Malleable Iron Research Institute; The Gray Iron Institute; The National Founders' Association; The American Society for Testing Materials; The American Institute of Mining and Metallurgical Engineers; The American Society for Steel Treating, and many

others; we do not attempt to assume their responsibility nor to do their work for them.

The Place of A. F. A. and Research

It is not the function of this Association to conduct extensive research; it is its function to make available to its members, so far as possible, the results of the research of others. Research, as we know it today, is largely the very careful study of minute problems. It is intensive, while the broad divergence in the interests of our members force us to deal with more general questions. It is very expensive; while if we are to be of value to the small units of our industry, our dues must be kept on a nominal plane. We have the opportunity, from time to time, to join with other organizations in co-operative investigations for the solution of certain problems. We can quite properly avail ourselves of every such opportunity to be of benefit to our members, but we should not assume that every research problem in the industry is ours, and that any one else who assumes to solve one is usurping our prerogative. But one of the glorious things about our great industry is the fact that, generally speaking, those units which have the resources or the ability to discover new facts, or improve old processes, are more than willing to share that knowledge with those not so fortunate, conscious that by and large they advance only as the entire industry advances; that, generally speaking, they are successful largely as their competitors succeed. To make such information available to all is the primary function of this organization.

Solution for Success of Foundry Industry Must Be Solved from Within the Industry

Nor is this a task to be lightly assumed. The greatest menace to the success of the foundry industry lies within it, and does not come from the outside. The successful casting of metals is an exceedingly complicated art; the difficulties of making sound castings are great, the variables in the processes, especially in making jobbing work, are numerous and hard to eliminate. Too often the designer, or the customer, considers the purchase of a casting of any sort as being more or less of a gamble to be avoided if

possible. Many times my own sales department has reported a customer who formerly used steel castings, who, influenced by a low price or other considerations, purchased from a company who furnished an inferior product, with the result that the customer re-designed his machines and eliminated steel castings. In the long run society will use that product which has best served her purpose; be it a casting, a forging, or a welded part, and no amount of propaganda can change its usefulness. The real job of this Association is to help the industry to furnish a product that will the better serve society's needs.

In the foregoing I have no desire to be dogmatic. It must be remembered that what I have said is but an expression of my personal opinion. Problems of business are full of constantly changing variables. They cannot be solved either by slide rules or formulae. I have attempted to set down principles which, to my mind, underlie successful progress. As problems arise these principles must be interpreted to meet them, for the problems are often complicated and lie so close to the border-line between what is wise and what is unwise, that a satisfactory solution can only be obtained by very careful judgment.

Character of Association

In closing I want to say just a word on the character of your Association, for organizations of this kind do have character, irrespective of presidents who come and go, like the changing seasons. In view of the fact that I had no connection with the work of this Association until I became an executive officer, I can with propriety say some things unbecoming in those who have served you longer. I have been a member of a good many boards of directors of various organizations, but never one whose personnel was of higher character or whose members were so conscientiously devoting their time and the best of their ability to the interests of the organization. There is a close association between foundrymen and the representatives of the equipment manufacturers, but I have never heard one of the latter advocating a policy which might be of immediate advantage to the equipment business, but of questionable advantage to the foundry industry. Their action has indicated that they feel that their own interests can best be advanced by that which best advances yours.

Of the character, energy, and ability of our Secretary, C. E. Hoyt, too much cannot be said—but you know him even as well as I do. He thinks of nothing but the progress of the work entrusted to him, and he handles every problem which confronts him in a manner which makes it a delight to work with him. Robert E. Kennedy, the technical secretary, fills his place well, and handles his work with efficiency and with a growing knowledge of the needs of the industry. Each member of the office staff is a credit to the organization. The money you contribute is handled as though it were a trust fund, and your finance committee is never asked to authorize expenditures whose objects have not been carefully analyzed both as to whether they will be of real benefit to the organization, and as to whether they represent the minimum possible expenditure to accomplish the desired object.

I have never known an organization in which I felt that those who represent the members in executing their work were functioning with higher ideals or with a more earnest desire faithfully to discharge the trust placed in them.

The Annual Banquet

Bellevue-Stratford Hotel

Wednesday Evening, May 16, 1928

President Utley, Toastmaster

TOASTMASTER UTLEY: Members of the American Foundrymen's Association, ladies, and guests: It is a great pleasure to welcome you all to this banquet in connection with the Thirty-second anniversary of the American Foundrymen's Association. As I listened to some of the men last night, who gathered in the Club across the way to talk of the time, thirty-two years ago, when this Association was born, as I contrasted the difference between its status then and now, I could not help being reminded of the story of the negro who desired to be a movie actor. He had been engaged to do odd jobs out on one of the Hollywood lots, and one day his director came to him and said, "Rastus, I've got a scheme; I am going to cast you in bed with a lion." Rastus looked at him and said, "No, no, boss, you ain't going to put me in bed with no lion." "Oh, yes, Rastus, that will be all right." "No, I ain't going to do that." "Oh, yes, that lion won't hurt you, that lion was brought up on milk." "Yes," said Rastus, "and so was I brought up on milk, but I eats meat now." (Laughter.) The very smooth and easy way in which this Convention so far has run, called to my mind by way of contrast the story of Ole, who was on the witness stand supposedly testifying relative to a wreck. Ole did not make a very good witness. The attorney who was examining him got a bit cross, and he thundered out to him, "Ole, you say that at such and such a time this night you were walking North and saw No. 8 coming South at a speed of sixty miles an hour?" "Yah," says Ole. "And then you say you turned around and looked behind you and saw No. 5 coming North at a speed of sixty miles an hour?" "Yah, yah," says Ole. "What did you do then?" "I got off the track." "What did you do then?" "Well," said Ole, "I thought that ban a damned funny way to run a railroad." (Laughter.)

As I take farewell of this office and stand for the last time with the opportunity of talking to you, I can't quite resist the temp-

tation to say a few words and to leave with you a few questions which have been running around in my mind for some few years, and which perhaps have been crystallized somewhat by this Convention. You will notice that I am down as both President and Toastmaster, and in the next few minutes I am going to be purely a toastmaster and not have anything to do with the President's job, because you know a toastmaster always has the privilege of saying anything he pleases and doing anything he pleases, whether it has any sense or not, and some of the things that I may say before I get through may not perhaps be connected with the functions of this organization.

How can we account for the fact that the income of the people of the United States for 1926 was equal to ninety per cent of the total wealth accumulated by all the people of the world from the time man first appeared up to the signing of the Declaration of Independence in this city one hundred and fifty-two years ago? How does it happen that in a single year this country produced nearly as much wealth as all the world had gathered together in all that time? If an increase in wealth is a sign of progress and if progress is the increasing share of more and more people in more and more of the good things of life, what are we doing to guarantee that those who come after us shall have opportunities for progress equal to those which have been given to us?

It seems to me that for this Association, this city of Philadelphia represents three birthplaces; first, the birthplace of the nation at the time of the Declaration of Independence; second, the birthplace of our Government when the Constitutional Convention was called; and third, the birthplace of this Association. Each one of these, unless I misinterpret history, represents a distinct and definite epoch in the story of the human race. The Declaration of Independence sprang first from the independence which was engendered in the hearts of men scattered far and wide in a new country by the struggle for survival in a wilderness, and second, from the philosophy of Montesque and the other French individualistic philosophers. It marked the point when the desire, the rage, if you wish, of the individual for absolute freedom, for absolute independence from the domination of his fellowman reached its height. The Convention which

was called to frame a constitution did not receive a great deal of support from those individualists who had signed the Declaration of Independence. They were not especially interested in "a more perfect union." The union of the old Confederation was quite good enough for their individualistic theories. The men of business, however, the men who owned the ships of New England, the men who did what little manufacturing there was to be done, the men who handled the trading of the colonies, insisted that they must have a government stable enough to enable industry to prosper. The Constitution of this country, although written in political language, is a business document, and if we would understand it we must realize that it was written primarily to make it possible for business to exist in this country. Now the third birthday was the formation of this Association. I am not prepared to say, and I have no desire to know whether this was the first great association formed or not. I do know, however, that in the ten or fifteen years succeeding 1896 we had the birth of so many thousands of associations that we cannot keep track of them. The attorney for one of the great trade associations told me a short time ago that in this country there are over three thousand trade associations alone, and in addition to them, there are technical associations and state associations and local associations and Boards of Commerce, and charitable associations, and nobody knows what not.

How did it happen that all these associations had their birth within a ten-year period? There must have been some reason for it. If we examine the situation for a minute I think we shall see that man suddenly made an astounding discovery, that for the first time, perhaps, in our particular civilization, he began to realize that his competitor did not wear horns, as he had supposed. He found that he was not the terrible creature he had pictured him, but that, like himself, he was quite a decent, normal human being. He found to his astonishment that this competitor knew something about his own business which he did not know. He began to realize he could get some benefit from associating with that competitor. Don't you see what was happening? The *individualistic* philosophy of the beginning of the nineteenth century had run its course; it was giving place to a *co-operative* philosophy which was introducing the twentieth century. Man

was beginning to be willing to lay aside some of his rights in order that he might associate more closely with some of his fellows, and from the love and esteem and the help of those fellows he found that he could get more of satisfaction than he had been getting by standing apart in the assertion of his rights.

The great thing which the Constitution of the United States gave to us, and the thing which made it a different political document than any that had ever come from the hand of man before, was the fact that it guaranteed to every man in this country, irrespective of who his parents might be, irrespective of the place in which he was born, the opportunity of developing to the highest, without let or without hindrance, the ability that the Lord had given to him. America is the America she is, not primarily because of her fertile fields, wonderful though they are, not primarily because of the wealth of her natural resources, great as that wealth is, but because the Constitution of the United States released the dynamic energy which was within her people and gave them the chance by the exercise of ability, of initiative, and of driving power to make the best of the resources which were placed before them.

But while men began to associate with each other in the beginning of this century, they began to do something else which was not quite so good. While they held out one hand to their fellows, and attempted to hold in the other the rights wrung from government through a period of hundreds of years, they began unconsciously to pass some of those rights back to government. Business began to lose its freedom of initiative. We began to give up some of our personal liberty. We began to find ourselves hedged in by boards and commissions which restricted our actions. Thirty-eight years ago, in 1890, the so-called Sherman Anti-Trust Law was passed, one of the great enigmas of all time; for, despite thirty-eight years of almost constant litigation, despite decisions by almost every court in the land, and numerous decisions by the Supreme Court itself, there is no lawyer in the country today who can interpret that law or tell his client with any degree of assurance what he can or cannot do under it. This statute is a relic of the dim and distant past, for thirty-eight years ago in our industrial civilization was the dark ages. It covers as great a span as a thousand years in our social civili-

zation. You and I in this Association, and other men in other Associations, can get together and talk about our costs and our production and the way that we can better improve our product and how we can better serve society, but we dare not talk one to the other about what we ought to get from society to recompense us for that better product, else, according to law, we have become criminals. There is a case pending in Cleveland now where the government, appearing before the Federal Court, seeks the indictment of the Lake Carriers' Association, alleging that they unlawfully conspired when they decided that they would not start the lake boats before the first of May. But up to the seventh of May the ice in White Fish Bay was so thick that all the power in all the steamers on the lake could not drive a single one of them through it. If the government is going to be consistent it will have to indict "Jack Frost," who made the ice, along with the men who "conspired" by saying that they would not wreck their ships by driving through it. All over this land today, we know that small concerns by the tens, by the hundreds, I am almost tempted to say by the thousands, are being combined into larger concerns; that men who have carried them through their formative periods are turning them over to others to handle. Of course, the excuse is that big combinations can operate more efficiently, but we all know that in many, many cases these combinations come about, not because of a desire for that efficiency, but because of the fact that the small competing concerns cannot get a price for their product which enables them to live, and they hope, by a combination, that a single sales manager can do that which a number of independent sales managers are prohibited from doing. I have no quarrel with great corporations; I have intense admiration for the Steel Corporation, and for the man who through these years has guided it on its course. In my humble judgment, he was one of the greatest statesmen, one of the ablest men that our generation has produced. But if we are to retain this principle of individual initiative, which I claim has been the real driving force of this country, which I claim has been the real producer of our wealth, then we must continue to protect the small companies as well as big corporations. We cannot afford to crush out this spirit of initiative, irrespective of how great efficiency we get

from some of the larger organizations. I am quite sure that it is better for posterity that we have thousands and hundreds of thousands of relatively small businesses in which few men are owners and have the feeling of responsibility and the desire for success that ownership produces, rather than that we have hundreds of thousands of high-salaried executives. We cannot continue to have this condition and conform to the present laws. We can no more turn aside economic law by a statute than you and I can change the action of metallurgical law in our cupolas by asking Congress to pass a bill.

If these things are true, my friends, isn't it fair, and isn't it time that we in industry, and especially in the manufacturing industry, ask that the government, which is frankly and openly urging the farmers to market their potatoes at co-operative prices, also allow us to co-operate in marketing our castings, without putting us in jail for doing it? Isn't it time that we asked that twenty-five small companies, co-operating together, have the same rights in the selling of their product as they would have if they combined themselves under one management and had one sales manager? Isn't it time that we asked that the Sherman Law, that last bulwark of the individualistic philosophy which existed a hundred and twenty-five years ago, which has given way to the co-operative philosophy of the present, pass out, along with the age of which it was a part? Isn't it time that we asked that we be allowed to arrange to sell our product at a profit rather than that eventually, forced by economic pressure, we be obliged to sell our souls to some great corporation in order that we may be able to save our bodies?

We of industry must solve these problems. We cannot pass them on to someone else.

Your Honor (turning to Judge Wells), I have the greatest respect for your great profession. I enjoy above everything else reading the life and the work of some of the great lawyers of our country, but I think, sir, that notwithstanding the fact that there are probably twenty or thirty times as many lawyers as there were a hundred years ago, if I were to ask you tonight to pick out from your profession fifteen men whom a committee of the American Bar Association would judge to be as able as the ablest fifteen men who practiced before John Marshall in the

early days of the Supreme Court in this city, you would find it exceedingly hard to do so. I say this not to cast reflection upon the legal profession, but because it seems to me that it bears out a feeling I have had that the lure, the romance, the ability to create which exists in industry today is calling to industry the best minds among the younger generation; that industry and the purely scientific professions are taking away from the other professions the best of the younger generation. Now, if we are taking into industry the best of the brains of the future, are we not also taking upon industry the responsibility to give clear thought, careful attention, honest, straightforward, fearless consideration to those questions which relate to handing down to posterity the heritage which has been handed to us? I am sure that if this civilization of ours is to escape the fate of the beautiful civilizations which have come and gone in the history of the world, it will do so only because of the intelligence, the integrity, and the ability of the men who direct industry, for industry alone is the thing that differentiates our civilization from the civilization of the past.

Presentation of the W. H. McFadden Gold Medal to Mr. Outerbridge

This morning, as I lay thinking over this convention, instead of getting to sleep, I began to wonder what of its impressions were going to last the longest. As I checked them over, it seemed to me that after the picture of the museum had gone, after the recollection of the papers had faded, after the memory of the convention had become rather dim, the thing that would stand out most clearly was the rugged, romantic character of a man I had met.

You know that it is customary at these banquets, acting on behalf of those who have made it possible, for us to present a medal to someone who has done something for the industry. The medal which is given tonight was provided by Past-President William H. McFadden, the romantic, rugged man who will stand out in my mind as the real character of this convention; a boy who, at the age of twelve, came from a West Virginia farm to be an apprentice in a foundry; who, at the age of fourteen, was sent to Europe by Mr. Carnegie on a very important mission:

who, at the age of sixteen, was the superintendent of a shop; who, in the first seven years in which he worked, received pay for four and a half years' overtime put in in addition to the regular long hours of his trade. A boy who labored for years to keep the roof above the head of his family; a man who today is in New York borrowing for his corporation more millions than you and I can count. The dramatic story of a wonderful man! Rough? Yes, if you will. Uncultured? Perhaps; but magnificent notwithstanding. And on the other side of the picture is a quiet, scholarly man who worked tremendously, but who worked quietly, that he might get the secrets of nature with which the man of action might accomplish his mission. In this simple ceremony we epitomize the dramatic story of American life; the driving power of the "frontier man" pays tribute to the scholar who furnished him with the tools with which to do his work; the brain which expressed itself in dazzling action meets in happy acknowledgment the brain which expressed itself in thought and meditation. We are especially fortunate in having with us a man who knew Mr. Outerbridge well, who lived with him and worked with him in a plant in this city, and I take great pleasure in introducing Past-President Carleton S. Koch, who, on behalf of the American Foundrymen's Association, will present the McFadden medal to the spirit of Mr. Outerbridge. (Applause.)

Presentation Speech by Carleton S. Koch

Mr. President, Dr. Outerbridge, Ladies and Gentlemen: I think you will all agree with President Utley that one of the pleasing touches of this convention is the fact that we have had with us Mr. McFadden. You probably are all well aware of the very active part he took in this Association work. Later he left the industry entirely, and afterwards, he gave the money, the income of which should be used in the recognition of work which was of particular advantage to the industry in which he had so long been active.

Last October the Board of Awards voted to give the McFadden Medal to Mr. Alexander E. Outerbridge, Jr., of Philadelphia. Only a few months thereafter, Mr. Outerbridge died, but the fact that his efforts had been so recognized we know was

most pleasing to him in the last few months of his life. His appreciation of what had been done is contained in his letters to several of us who knew him, and these letters are literary gems; they certainly reflect the culture and the high character of Mr. Outerbridge.

We are here tonight to honor a man who was deserving of it, not only by reason of his activity and work in foundry metallurgy, but a man whose general attainments were far beyond those of the average man. The Bulletins of the Association have enumerated most of the things which he has done, and perhaps only one need be mentioned here tonight, and that is the work which he did in regard to the subject of mixing foundry iron in the cupola by analysis rather than by fracture.

At a time when the pig iron manufacturer and the gray iron foundryman and the technical press were actively discussing this point, the foundry to which Mr. Outerbridge was attached, was quietly running along producing a very fine type of casting by this method. It is no doubt true that he was the first one to really put this thing into any kind of scientific shape and to apply it in the foundry. It is probably true that if a thorough investigation could be made, it would be found that he was the originator of this method.

He did a great deal along many other lines, but I am acquainted with the fact and make the statement that I think perhaps his greatest attribute was his ability to put into practical form those things which he discovered or which had been discovered by other people. It is perhaps debatable today whether the ability to apply things is not more rare than that to discover new things. We have much knowledge in our foundry industry that is not being used. The need we have today is for men who can put into practical operation the results of recent research. We had here a man who could do that very thing. Mr. Outerbridge supplemented his investigations, his experimental work and his adaptation of discoveries with his writings, and from some of his personal papers I learned that he wrote more than one thousand articles on scientific subjects, which have appeared in printed form in one way or another. The first that I could find on any foundry subject was in 1881, forty-seven years ago.

1850 A. E. OUTERBRIDGE, JR. 1928

Mr. Outerbridge kept nothing back, and the company to which he was attached gave him free rein in publishing much of this matter. In his papers I have also found a letter written by a fellow foundryman. The first part of this letter is taken up with the fact that two men had prepared a paper and presented it before one of our scientific societies, and in this paper assumed originality. The fact of the case was that Mr. Outerbridge had published this some years previous, and the writer of this letter was very much disturbed about this. The second part of the letter reads as follows:

"It seems to me that you should devote some time to writing up 'Memoirs of a Foundry Metallurgist,' in which you can trace the rich developments in the foundry you have brought out yourself and have been in contact with. It would fix the history of the art definitely for the information of future generations. Such occurrences as the appropriation of your ideas by these two men would thus receive their proper setting."

This letter was written in 1917 by our good friend Dr. Moldenke. Perhaps as well as any other man, Mr. Outerbridge could have written a book on the development of the gray iron industry in the last fifty years; and if this be true, it alone should be sufficient for the award of this medal.

In passing, it should not be overlooked that his abilities were sought after and used by civic and governmental institutions. One which I personally remember was the fact that he was brought into the matter of the crack in the Liberty Bell, which at that time was giving great concern. Another one, which we do not think so much of nowadays, is the fact that he spent much time with the fire insurance people and the underwriters in regard to the use of gray iron in building materials. This was due to the great study that he had given to the matter of the growth of gray iron under heat.

He was a prominent man in the Franklin Institute of this city, and had several times been honored by them publicly.

We therefore have a man who was, first of all, a cultured gentleman; then one of marked attainments in regard to foundry investigations and other scientific subjects; and third, a writer of some repute.

Accordingly, the American Foundrymen's Association, in awarding this medal to Mr. Outerbridge, honors itself and so records its judgment and its appreciation of his accomplishments, and in years to come foundrymen will read in the records of this Association that in the latter part of the nineteenth century and the beginning of the twentieth century, there lived in Philadelphia, a man who did things that had not been done before and that were worthy of notice and consideration by his contemporaries.

Regrettable though it may be that Mr. Outerbridge is not here tonight, still we are pleased in presenting this medal to have the acknowledgment by Dr. George W. Outerbridge, his son.

Dr. Outerbridge's Reply

Mr. President, Mr. Koch, Ladies and Gentlemen: In accepting this very marvelous award as a very poor representative of my late father, I wish I could convey to the members of this marvelous organization just a little idea of the wonderful thing it was to him, coming when it did.

Mr. Koch has spoken of his appreciation of it. That was most vivid and most real. This award came to my father at the absolutely psychological time. For some years his health has been failing; he had been obliged to spend many of the winter months each year in the south for four or five years, but nevertheless he had tenaciously held to his position, to his work. He often said, "When I have to give that up, then I am done, I will die, I have no further interest in life."

Finally, last summer, he was forced to the realization that his physical infirmities would no longer permit him to carry on his activities, although his mind, to the very last day of his life, was as clear as it ever was, and it was only shortly after he had definitely put on paper his resignation from his position with the William Sellers & Co. organization in this city, which he had held for very nearly forty years, just shortly after that, when, as we all know, any man will be somewhat depressed, when he feels that he is done, that his lifework is over, that he has nothing more—then came this remarkable testimonial from this organization, whose standing, of course, in the world my father thoroughly

recognized and appreciated. It was the greatest possible tonic; there was nothing more that the medical profession could do for him; there was, I think, nothing that could have happened in his life that would have given him such a fillip, such an interest, such a driving spring to carry him on those succeeding three months which he lived, as the announcement of this award. It was the greatest possible joy and delight to him, and, of course, to all the other members of his family, and not only did he appreciate tremendously the fact of his having been considered for this great award, but he appreciated very much the delightful way in which it was done, the courtesies that were extended to him by some of the members of the organization, Mr. Clamer particularly, who went down to Atlantic City specially to see him, where he was at that time, to tell him about it. The remarkably accurate and interesting little biography of him which was gotten up by some of the members of this organization, and which, when submitted to him for his approval, astounded him that the facts could have been brought out and developed, and I can assure you that it brought to others, the other members of his family, facts in his life which none of us knew or appreciated or realized at all, and not only did it do these things, but it gave him another tremendous point of interest, in that the publication of the announcement of this award, which was fairly widespread in this part of the country, brought to him a swarm of letters from men with whom he had lost contact for years, old friends, old colleagues in the foundry profession, men whom sometimes he had almost forgotten about—brought in swarms of these letters at a time when he was cooped up in a hotel room in a very poor physical state, and that was the final great interest and joy and delight that my father had.

And so, Mr. President and Mr. Koch, I wish to express, on behalf of my late father and of all the members of his family and of myself, our most intense appreciation and thanks for this very remarkable award.

The banquet program was concluded by an inspirational address by Judge Harold B. Wells.

Address by President Utley at the Exhibitors' Dinner

Benjamin Franklin Hotel

Monday Evening, May 14, 1928

Criticism is often made that this scientific and industrial civilization, of which you and I are an active part, is too largely materialistic, that we in industry think of nothing except making money and that we have lost many of the fine attributes of former civilizations. I am going to trespass upon your time tonight to discuss this question in what may perhaps be a rather whimsical manner.

Some weeks ago during the first All-American Aircraft Exposition in Detroit, as I sat in an easy chair in the living room, my wife turned on the radio. From it there issued a voice I had heard many times, speaking as quietly and as distinctly as though its owner sat on the other side of the table:

"This is station WWJ, Hy Tyson talking. We are broadcasting tonight from a three-motor airship. I am talking to you as I fly at the speed of 100 miles an hour, 5000 ft. above Detroit. After the next speaker has finished we shall return to the Ford Airport and then go down to the Aviation Banquet. If Harvey Campbell is listening in I wish he would be sure and save some food for us, for we are hungry."

As my dazed mind endeavored to realize the import of these simple words, my eyes rested on a copy of Will Durant's "Story of Philosophy" which lay upon the cabinet whence came this voice. Shades of the great minds of the past! Spirit of Aristotle and Plato and Socrates, which speak to me from out these pages, *what does this thing mean?* Suppose that your disembodied spirits could step forth from between those covers and could sit down beside me in this living room, what would you think? Suppose you could realize that the voice you have just heard is not mighty Zeus, thundering from the topmost throne of high Olympus, but the voice of a fellow human being, borne to your ears not by a chariot of fire, but along the waves of

ether, even as light from the far-distant sun. Suppose you could realize that mounted on the back of a great eagle that man is talking to you from out the cloudless sky a mile above your head. Suppose you could realize that you too might mount upon the back of that eagle, and that without complaining, the great bird would carry you for hours and days a farther distance than the farthest confines of the earth that you knew when you were here. Suppose you knew that you too could send your voice along the waves of ether, and that you could make your own voice heard by more people who knew you and loved you than inhabited the entire earth at the time you lived among us mortals. What would your reaction be? Would you say that the scientific and industrial civilization which had produced these marvels was inferior to the civilization you knew on earth? Would you say that the men who had wrought these things were living for a less noble purpose than did your fellow men? Or would you say that by some miracle which you could not possibly explain this civilization had given to mortal man powers far greater than your minds had been able even to conceive of as belonging to the Gods; would you not say as you looked upon the comforts of our life that by some unknown power we had so transformed the earth that it exceeded your fondest dream of HEAVEN ITSELF.

No, this isn't a miracle. The Gods haven't given us anything that you didn't have. Our minds aren't any better than yours, though perhaps we are using them in a different way. There are still just 24 hours in our day and each one of us, be he the most industrious or the most indolent, has exactly the same number of minutes in which to accomplish his work.

Of the 400,000 people who lived in the Athens of your time 250,000 were slaves and lived not for themselves but for their masters. We have liberated all these people and we've organized society so that they work for us, not by a form of socialism which you so often discussed and so rightly condemned as being useless and ineffective, but by what we call "business." We've taken the steam you used to see rising from the kettle and the lightning that used to play around the mountain tops, and we've harnessed them up so that they do the work that your slaves used to do, and because the sons and daughters of your slaves

have these machines they are able to live as did your kings. We've frankly recognized the fact that "love is the greatest thing in the world," that a man will work harder to advance the interests of himself and his wife and his children than through any other motive, and so we have arranged it that when he does something that benefits all of us he gets a part, and we get the rest. He sometimes fools himself and thinks he is working only to make himself rich, but if he does something for which he gets a lot of money he has benefited the rest of us far more than himself. If he only carries in the wood from the hillside and brings the water from the spring his reward isn't very great, because there are so many who are glad to do this sort of work, but if he has a new thought and is one of those daring souls who is willing to stake his life on his ability to accomplish something which everybody says can not be done, and he accomplishes something that the rest of us all want, then we give him a lot of money as his reward and that encourages other people to do great things for us. No, it doesn't work out perfectly. Sometimes a man has a great thought or dream which doesn't come true because society hasn't advanced to a stage where it realizes that it needs it; sometimes the idea, wonderful though it may be, can't be harnessed up with our present mechanical development so it will be of service to us, and in these cases he doesn't get the money and we don't get the benefit. Oh, Socrates, they gave you the cup of hemlock not because your ideas were not sound, but because your contemporaries hadn't progressed far enough to appreciate them, and human nature hasn't changed much since your time.

You see with our system it isn't enough that the thinker or the inventor or the research man has a great thought, but it has to be put in such shape that it is of practical benefit to all of us, and often the work of the manufacturer is far harder than that of the inventor.

In addition to getting everyone who has ability to work for us, the art of printing has made it possible for each man to start where his predecessor left off. Society knows what the other fellow has accomplished. She goes on getting the benefit of his work, but she doesn't pay anyone for doing it over, and so no one wastes his time on it. In your time the day was rather short,

your torches didn't give light by which one could paint or study, but years ago someone found a way to make a lamp which would burn oil out of the earth and some poor boys perfected a means of distributing the oil so that any man anywhere in the country who really wanted it could have it. We made these boys the richest men in the world, but you see they deserved it, because we didn't have to go to bed when the sun went down, we could work all through the night, and so the boys who were young, and strong and ambitious used to burn the midnight oil working and thinking of ways in which they might make money and by making this money for themselves they have brought all these benefits you see about you. In your time, the speed of a horse was the fastest means of locomotion that you had. Through a century and a half of work on the part of thousands of men, each one adding a little to what the others had done before him, we can go further between the rising and the setting of the sun than you could in a month of constant traveling. Our great improvements have been in increasing the usable time in our 24 hours, by banishing the darkness and by increasing the speed of transporting either ourselves or our thoughts, so that while we haven't any more hours in our day than you had we can accomplish many, many times as much as you did.

Oh, no, you are mistaken. Money isn't the only thing in our world, although there are some foolish people who perhaps think it is. We are coming to realize that you had great businesses in your day, that your silver mining industry turned the tide of the world's history and gave us the civilization we know; that your great grain trading industries, your banking business were worthy predecessors of some of our industries, but we have no knowledge of your wealth. We do know that the income of our country last year alone was 75 per cent of the total wealth of the entire world a century and a half ago, and it must have been many times the total wealth of the world when you were here. But this wealth isn't money, it's things we people want, it's food, clothing, shelter, it's flocks, and herds, and those inanimate slaves that we call machines. Money is only the counter we have to measure these things of real value so that we may handle it the more easily. True, there are some foolish people—most of them young and short-sighted—who work only with the thought that

by some hook or crook they may get money in large quantities, but the great majority after they have acquired enough for their daily wants are spurred on by the desire to accomplish some object, accepting the acquiring of riches as an acknowledgment by society that they have succeeded. I have never seen any rich man who showed any signs of being happy simply because he had money. Its worship, unfortunately, comes from those who haven't it and who erroneously think that its possession will bring happiness. But the only real satisfaction comes to rich and poor alike from a knowledge of work well done and from the love and respect and esteem of their fellowmen. Our real progress is the bringing about of a condition where *more and more of the people* can have *more and more of the good things of life.*

You must leave me and go back between those covers? Oh, I am sorry. I wish you could stay. We need you badly here on earth again. In your day, men worked from sunrise to sunset and had little time for anything else, but our industrial system has cut down the working time to eight or nine hours, and gives us the balance for ourselves. One of the greatest unsolved problems of our civilization is how to employ this time for the greatest benefit of each individual. Unfortunately, many of our teachers and our preachers who should be providing the solution for this great question are spending their time and their energy berating us of industry because of our success, endeavoring from their ignorance to tell us how to handle our business instead of endeavoring to reach a solution of this great problem which confronts them. Would that the inspiration of your presence and the genius of your great minds might aid us in this problem on which the future of the race so vitally depends. But as you go, I wish you would take with you these few words, for the poet has expressed my thoughts much better than I.

"Business is Business," the Big Man said,
"A battle to make of earth,
A place to yield us more wine and bread,
More pleasure and joy and mirth;
There are still some bandits and buccaneers
Who are jungle-bred beasts of trade,

But their number dwindles with passing years
And dead is the code they made."
"Business is Business," the Big Man said,
"But its something that's more, far more;
For it makes sweet gardens of deserts dead,
And cities it built now roar
Where once the deer and gray wolf ran
From the Pioneers' swift advance;
Business is Magic that toils for man,
Business is True Romance.
And those who make it a ruthless fight
Have only themselves to blame
If they feel no whit of the keen delight
In playing the Bigger Game,
The game that calls on the heart and head,
The best of man's strength and nerve;
"Business is Business," the Big Man said,
"And that Business is to serve!"

Report of the Executive Secretary

The summary of the proceedings of the 1928 convention records our technical activities. The report for the Board of Directors will show the minutes of all Board meetings and the report of the Manager of Exhibits records statistical information covering that activity. We submit herewith our report on membership.

Membership

The membership statistics given are for ten months, January 1st to October 31st. During that period there have been a total of 89 resignations and delinquents in class A or firm memberships and a total of 107 class A members elected, a net gain of 18. During the same period 81 class B and junior members either resigned or were delinquent and only 76 were elected, a net loss of 5 in this class and a net gain of 13 in both classes. There is naturally a greater turnover in individual members than in firm members due to changing positions. A large percentage of the loss in firm members can be accounted for by foundries being closed down or going out of business.

Of the total book membership of 2,343 on October 31st, 2,189 are in the United States and 154 in 18 other countries, distributed as follows: Canada 85, England 23, Australia 5, Scotland 3, Belgium 1, Czechoslovakia 2, France 4, Germany 3, Holland 3, Italy 4, Japan 9, Luxembourg 1, Philippine Islands 2, South America 1, Spain 2, Sweden 3, Switzerland 1, United States of Soviet Russia 3.

Book membership January 1, 1928			2,330
New members to October 31, 1928			183
			2,513
Resignations:	Class A 77		
	Class B 34		
	Junior 1	112	

Delinquents:	Class A............12		
	Class B............41		
	Junior 5	58	
	—	—	
Total dropped to October 30, 1928......................			170
			2,343
Class A (company memberships paying $12.00 dues).....			1,693
Class B (additional memberships paying $7.50 dues).....			551
Foreign, paying $10.00 dues............................			69
Junior, paying $5.00 dues..............................			8
Honorary			22
			2,343

Convention and Exhibit

In our report a year ago commenting on the successful Convention in 1927 without an exhibit, we expressed the belief that the foundry industry suffered a distinct loss when a year passed without a big convention and exhibit being held. We now reaffirm our belief that these events, attracting thousands of foundrymen, give a great stimulus to the industry and are an inspiration to do bigger and better things. Surely if the increase in volume of business done by foundry equipment manufacturers in 1928 over 1927 is a criterion, the benefits of the annual exhibits fully justify all the expense to exhibitors.

1929 Exhibit

The compromise experiment of a limited exhibit in 1929 will be looked forward to with great interest and will, we believe, be of far greater value to both the foundry and foundry equipment industries than a convention with no exhibit at all.

It is our privilege to express for the officers and directors appreciation for the splendid cooperation of all authors of papers and of committee members who have given so generously of their time. For the support of President S. W. Utley, Vice-President S. T. Johnston, the Board of Directors, and the cooperation of all members of our staff, we express warmest appreciation and thanks.

Respectfully submitted,

C. E. Hoyt, *Executive Secretary.*

Report of Manager of Exhibits for the Year 1928

As a matter of record we submit the following report as a brief summary of the Exhibit held in conjunction with the 32nd Annual Convention of the American Foundrymen's Association. The Exhibit was held in Exhibition Hall of the Commercial Museum buildings at Philadelphia. The opening hour was 10:00 A. M. Monday, May 14, and closing hour 5:00 P. M. Friday, May 18. The Exhibit was open daily between the hours of 9:00 A. M. and 5:00 P. M. with the exception of Tuesday, when the closing hour was 10:00 P. M.

This was the third largest exhibit in the history of the Association, both as to number of exhibitors and amount of space occupied. There were 239 exhibitors using a total of 75,238 square feet. This was exclusive of space used for the castings exhibit and pattern making and molders' apprentice contest exhibits. The total number of exhibitors was 28 less than at Detroit in 1926 and 7 less than at Columbus in 1920. The total space used was 5,762 square feet less than was used at Detroit and 1,362 square feet less than was used at Columbus. The average of 314 square feet plus for each exhibitor established a record.

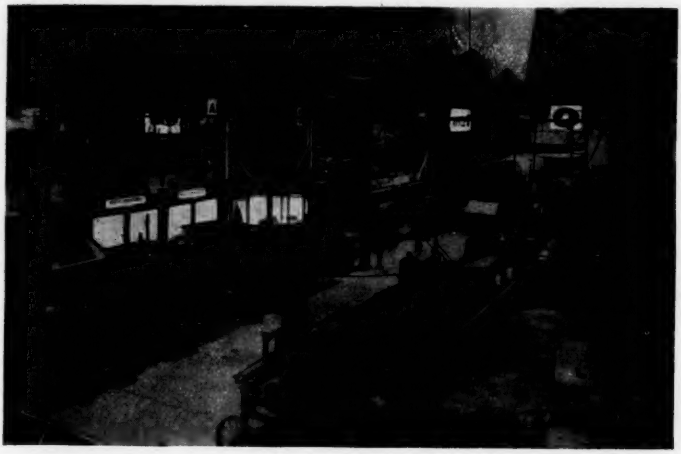
There are advantages and disadvantages in having exhibits such as ours all housed in one building. The ideal arrangement is to have two buildings, one for the quiet and non-operating exhibits and the other for the noisy operating ones, so arranged that visitors pass through the non-operating building or room to reach the operating section, a combination, however, that is seldom available.

This report would not be complete without an expression of appreciation from the Board and from the Manager of the splendid cooperation of foundry equipment and supply manufacturers in helping to make the Philadelphia Convention a great success and a credit to the great foundry industry of this country.

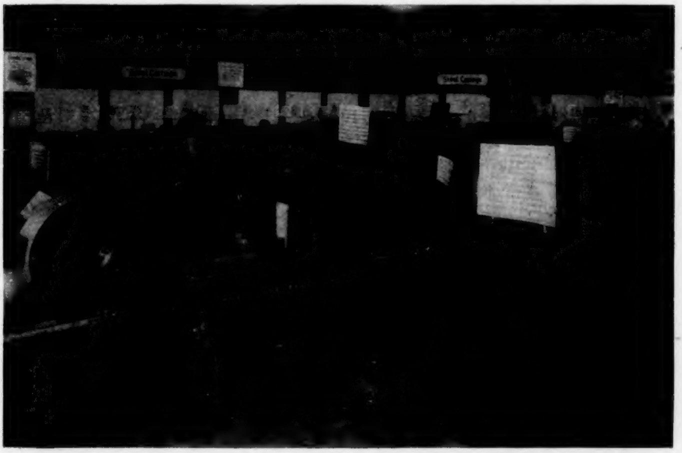
Respectfully submitted,

C. E. Hoyt,

Manager of Exhibits.



A PORTION OF THE 1928 EXHIBIT OF FOUNDRY EQUIPMENT, AND SUPPLIES HELD IN THE PHILADELPHIA COMMERCIAL MUSEUM



AN EXHIBIT OF STEEL, MALLEABLE AND IRON CASTINGS, WAS HELD FOR THE FIRST TIME IN CONNECTION WITH THE PHILADELPHIA CONVENTION.

Report of the Treasurer

We go to press with this copy of the Transactions, containing the proceedings of the Philadelphia Convention, before the close of the fiscal year and the books of the Treasurer have been audited. We show, therefore, with this report the auditor's latest statement made for the year ending December 31, 1927. A consolidated balance sheet for the technical and exhibit departments is shown, also a statement of receipts and disbursements for the technical department.

Without an exhibit in 1927, there were no receipts from that source and the auditor decided to carry the expenses of the department of exhibits forward as an expense on account of the 1928 exhibit. This item of expense is shown in the consolidated balance sheet. The audit of December 31st this year will show receipts and disbursements for the department of exhibits covering a period of two years.

Since the audit shown was made, bonds of $15,000 par value have been added to reserve. This, together with interest, makes the total amount in this fund as of November 1st $39,707.30.

In the unaudited financial statement presented to the Directors at the annual meeting on July 16th, receipts and disbursements for both the technical and exhibit departments for 18 months, January 1, 1927, to July 1, 1928, were given. With this was a statement of estimated receipts and disbursements to December 31st. These statements, covering two full years during which time two conventions and one exhibit were held, were made that the Directors might know how the two year financing program adopted following the Detroit Convention had resulted.

In these statements it was estimated that the excess of income over expenses would be $14,650.00, approximately 10 per cent of the gross income or 5 per cent per annum for the two year period. This excess of income, if realized, can be used to splendid advantage in financing increased Association activities.

The auditor's statements are shown on the following pages.

Respectfully submitted,

C. E. Hoyt, *Treasurer.*

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC.

BALANCE SHEET

AS AT DECEMBER 31, 1927

ASSETS

ASSOCIATION ASSETS		
Furniture and Fixtures	$ 1,470.99	
Less Reserve for Depreciation	944.82	
	$ 526.17	
Cash in Bank	2,752.08	
Accounts Receivable	602.00	
Supplies on Hand	884.25	
Due by Cleveland Research Fund	658.71	
		$ 5,423.21
EXPENSES PREPAID on account of 1928 Exhibit		18,272.47
		$23,695.68
CLEVELAND RESEARCH FUND		
Cash in Bank		1,419.60
AWARD FUNDS		
Investments	$21,520.10	
Cash in Bank	1,283.94	
Total Award Fund Assets		22,804.04
RESERVE FUND		
Investments	$23,634.22	
Cash in Bank	485.34	
Total Reserve Fund Assets		24,119.56
TOTAL		$72,038.88

LIABILITIES

ASSOCIATION LIABILITIES		
Loan—Harris Trust & Savings Bank	$ 8,000.00	
Dues Paid in Advance	139.50	
Exhibitors' Permits Paid in Advance	3,225.00	
Sand Research—Unexpected Appropriation	149.49	
Steel Castings Test Fund Unexpended	267.39	
Total Association Liabilities	$11,781.38	
Surplus	11,914.30	
		$23,695.68
CLEVELAND RESEARCH FUND	$ 760.89	
Appropriated for Cast Iron Research	658.71	
		1,419.60
AWARD FUNDS		
Principal of Funds	$21,000.00	
Premiums on Investments	520.10	
Unexpended Income	1,283.94	
		22,804.04
RESERVE FUND		24,119.56
TOTAL		$72,038.88

I have examined the books of the American Foundrymen's Association, Inc., for the year ending December 31, 1927. In my opinion the above Balance Sheet correctly reflects the condition of the Association as at that date.

ROBERT T. PRITCHARD,
Certified Public Accountant.

Chicago, January 14, 1928.

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC.

Technical Department

CASH RECEIPTS AND DISBURSEMENTS FOR THE YEAR 1927

Cash in Bank—January 1, 1927			$ 3,578.41
RECEIPTS			
Dues and Subscriptions		$24,891.86	
Convention Registration Fees		427.00	
Exhibitors' Permits (1928 Exhibit)		3,225.00	
Sand Research—Appropriated by Exhibit Dept.	$1,600.00		
Expended	1,547.80		
		52.20	
Steel Castings Test Fund Receipts	$1,077.29		
Expended	809.90		
		267.39	
Interest on Bank Balances		150.05	
Total Receipts			29.013.50
			$32,591.91
DISBURSEMENTS			
Expenses			
Auditing		$ 225.00	
Committee Meeting Expense		1,306.37	
Convention Expense		1,482.95	
Discount and Exchange		92.94	
Dues of Other Associations		50.00	
General Expense		10.00	
Office Expense		226.18	
Postage		2,031.89	
Printing and Stationery		1,755.51	
Publications		11,912.98	
Rent		740.00	
Salaries—Executive and Technical Secretaries		7,550.00	
Stenography and Clerical		1,932.27	
Telephone and Telegraph		63.40	
Traveling Expense		361.89	
			$29,741.38
Furniture and Fixtures		7.65	
Cast Iron Research		658.71	
Unpaid Items of 1926		68.74	
			735.10
Total Disbursements			$30,476.48
Cash in bank December 31, 1927			$ 2,115.43

Annual Report of the Board of Directors

To Members of the American Foundrymen's Association.

Gentlemen:

We submit herewith for the Directors a report covering meetings of the Board during 1928.

The first meeting of the year was held at Philadelphia on the evening preceding the annual convention. This meeting followed the annual alumni dinner of past officers and directors. The time was devoted very largely to considering some plan of Association activity for creating a casting consciousness and greater use of castings. Following discussion, the appointment of an Educational Committee was authorized.

The guest of honor at this meeting was Wm. H. McFadden, President of A. F. A. in 1907 and donor of the Wm. H. McFadden Gold Medal.

Annual Meeting

The annual meeting of the Board was held in Chicago, July 16. Reports of the Executive Secretary, Treasurer, Technical Secretary and Manager of Exhibits were received.

The report of the judges on apprentice contests was approved and awards authorized. The report of the judges for the Obermayer Prize Contest, recommending that no award be made, was approved.

President Utley submitted a report outlining activities of the proposed Educational Committee.

Recommendations of the Committee on Cast Iron for a research program in cooperation with the Engineering Foundation were received and referred to a committee of three to report back at a later meeting. The appointment of a committee of five on research appropriations was authorized.

A resolution favoring a survey by the Government on apprentice statistics was approved.

A resolution on the proposed steel casting specifications adopted at a members' session was received and acted upon.

Recommendations of the Cost Committee for each branch of the casting industry were approved.

Recommendations of the Committee on Molding Sand Research were received and certain tentative standard and standard methods of test were approved.

Malleable furnace refractory standards acceptable to the Division of Simplified Practice of the Department of Commerce of the U. S. were approved.

The resignation of Director W. D. Goldsmith was read and accepted.

The appointment of a committee of three to consider the appointment of a joint committee to draft uniform trade customs for the casting industry was authorized.

Following a report showing officers and directors elected at the annual convention and the election of Stuart Wells Utley to Honorary Membership, the meeting adjourned.

Meeting of New Board

The third meeting of the Directors was also held in Chicago on July 16 immediately following adjournment of the meeting of the retiring Board. The meeting organized by the election of officers and Executive Committee. H. Cole Estep was elected a Director to succeed W. D. Goldsmith, resigned.

The appointment of a nominating committee to select a ballot for the election of four members of the 1929 Nominating Committee was authorized.

It was voted to hold the 1929 Convention and a limited Exhibit at the Stevens Hotel, Chicago, in April, 1929.

With this report we show the minutes of the meetings of the Board.

Respectfully submitted,

C. E. HOYT, *Executive Secretary,*
For the Board of Directors.

Minutes of Meeting of Board of Directors

American Foundrymen's Association

Held at

Bellevue-Stratford Hotel, Philadelphia, Pa.,

Sunday Evening May 13, 1928.

Following the annual Alumni Dinner, a regularly called meeting of the Board of Directors of the American Foundrymen's Association was held, with President S. W. Utley presiding.

The following members of the Board were present: S. W. Utley, S. T. Johnston, Fred Erb, J. L. Jones, H. S. Simpson, M. W. Henley, N. K. B. Patch, S. C. Vessy, L. C. Wilson, A. E. Hageboeck and C. E. Hoyt.

Past presidents, members of the Advisory Board present were, Wm. H. McFadden, L. L. Anthes, Alfred E. Howell, R. A. Bull, B. D. Fuller, C. S. Koch and G. H. Clamer. Others present were Technical Secretary R. E. Kennedy, former Secretary Dr. Richard Moldenke, and Walter Wood, President of the Philadelphia Foundrymen's Association, also former Directors C. B. Connelley, T. S. Hammond, V. E. Minich and T. W. Pangborn.

In opening the meeting President Utley announced that he was going to present a matter which he considered of great importance to the foundry industry, a matter which he felt should be carefully considered by the Board before any action was taken. Continuing Mr. Utley said, "The first thing I wish to bring before you is the general scope of the Association's activities, and the question resolves itself 'Can the American Foundrymen's Association become an Association which will be representative of the foundry industry as a whole, or must we, if we are to perform our functions, continue to confine ourselves somewhat more closely to the technical side of the industry?'

"The second thing I wish to bring to you is this. We are all foundrymen, we are all united, but nevertheless we have different interests and activities. Now it seems to me, and I am speaking for myself and I may be wrong, that this Association cannot take in all of the work of the foundry industry; that it must confine itself to certain lines; and that its real field is to endeavor to solve those problems and discharge those duties in a particular prescribed field to the best of its ability to get as near a solution as we can, rather than a half or a third of a solution for a lot of problems, because that would not get us anywhere.

"It seems to me safe to say that this Association cannot go into the merchandising of the products of its members. We can urge upon our

members the policy of a price based upon cost of production, and we can point out ways that the cost can be arrived at, but we should not assume the responsibility of working these things out for them.

"The foundry industry is in a peculiar situation. It is one of the oldest industries in the world, and therefore people feel there is little left to tell about it. You seldom see a foundry story on the front page of a newspaper. Take such things as radios, airplanes, etc., and they get on the front page because they are something new and have a lot of human interest.

"It is probably true that the engineer thinks of a casting oftentimes as being something to avoid. He tries to get away from it if he can. Perhaps many of you know that a great many engineers do not know about the wonderful progress that has been made in the production of a satisfactory product, and it seems to be entirely within our province to take steps to inaugurate a campaign of education regarding the development of castings. I believe we should wage a campaign of propaganda in favor of the use and in extension of knowledge of the use of castings for all work.

"Now the suggestion that I would like to make and the recommendation to the Board is that it is within the province of this Association to do something along this line, and I would suggest that a committee of perhaps ten be appointed by the President of this Association, all members to be members of the American Foundrymen's Association, not a joint committee. I think it would be advisable to have this committee consist of, for the present, two gray iron men, two steel men, two non-ferrous men, two malleable men, and two equipment or supply men. This committee would work in connection with trade associations already in existence. I would advise the following activities:

"(a) That the committee prepare casting exhibits, and that these be shown at engineering schools.

"(b) Prepare and show, as it may present itself, motion pictures of various things of the foundry.

"(c) Get out pictures showing the scientific value of iron and steel.

"(d) To hold conferences in engineering schools and universities. Many of the schools have been having these conferences during the past few years on other engineering subjects. I believe that we should arrange, where possible, to have speakers at these conferences of the engineering schools and before engineering societies.

"(e) To arrange for the publication of articles of news value relative to castings.

"(f) Publish information about other materials that have failed in service. If this is properly done, many of the engineers will change back to castings.

"(g) Tell the buying public that there is something more than 'pound castings'; that they should consider the character of the foundry, its engineering ability, etc.; that all this has a commercial value to the customer

as well as the metal produced, and that the wise buyer must consider these facts as well as the pound casting that he is trying to buy.

"That is about as far as I can go in my recommendations for action at this time, and it is only after the most careful consideration that I have submitted this for your consideration."

President Utley ended his talk by stating that he wanted to hear from all the directors and past directors present. Following a lengthy and interesting discussion, it was moved and seconded that the chair be instructed to appoint an Educational Committee such as was outlined in his opening remarks.

Following a further discussion, President Utley said that if he was authorized to appoint this committee, he would work the plan out a little more carefully, getting it in more definite shape and present it at the next meeting of the Board. The question was then called for and carried unanimously.

The Chair called for a discussion on the subject of a program for future conventions, stating that it was not necessary to take action at this meeting, but that it was advisable to give the matter some thought. He then called on Mr. Hoyt to present the subject. A discussion followed but no action was taken.

Wm. H. McFadden, President of the Association in 1907 and donor of the Wm. H. McFadden Gold Medal of the Association, gave an interesting talk on early Association history and gave his views on activities the Association should engage in for the advancement of the foundry industry.

On motion duly seconded, a resolution was unanimously adopted recommending the election of Stuart Wells Utley to Honorary Membership in the American Foundrymen's Association, and the Secretary was instructed to present the resolution at the annual business meeting of the Association.

The meeting then stood adjourned to meet again at the call of the President, should there be occasion for another Board meeting during convention week.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. W. Utley, President.

Minutes of Annual Meeting 1927-28 Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

THE STEVENS HOTEL, CHICAGO, ILL.,
10:00 A. M. MONDAY, JULY 16, 1928.

President S. W. Utley presiding.

Roll Call

The following responded to roll call: President S. W. Utley, Vice-President S. T. Johnston, Technical Secretary R. E. Kennedy, and Directors Fred Erb, J. L. Jones, L. W. Olson, N. K. B. Patch, S. C. Vessy, L. C. Wilson, E. H. Ballard, A. E. Hageboeck and C. E. Hoyt.

Directors-elect B. H. Johnson and P. J. Krentz, and past presidents B. D. Fuller and H. D. Miles were also present. R. A. Bull arrived later.

Approval of Minutes

The minutes of the annual meeting held at Mansfield, Ohio, October 14, 1927, as printed in bound volume of Transactions No. 35, were approved without reading.

The minutes of the meeting of the Board held at Philadelphia, Pa., May 13, 1928, were approved as read.

Report of Executive Secretary

The report of the Executive Secretary was read and on motion was accepted and ordered placed on file.

Report of Treasurer

The report of the Treasurer reviewed financial operations for the period January 1, 1927, to June 30, 1928, showing that the total receipts from all sources were $148,939.65, expenses $112,903.18. Excess of income over expense for the eighteen months' period of operation, $36,036.47. Estimated expense from June 30 to December 31, $21,385.00. Estimated excess of income over expense for the two years ending December 31, 1928, $14,651.47.

Special Funds

The report showed a balance of $647.59 in the Cast Iron Research Fund, $267.39 in the Steel Casting Tests Fund, and a deficit of $748.39 in the Sand Research Fund.

The balance in the Interest Fund of the major awards was given as $1516.75; in the Obermayer Prize Fund $47.32.

The total of the Reserve Fund in bonds and accumulated interest was given as $24,559.79.

The report stated that it was the recommendation of the Finance Committee that the books and accounts of the technical department and exhibit department be combined in one account.

The Treasurer recommended that after an adequate working capital had been decided upon, that the balance of cash in the general fund be invested in good interest-bearing securities.

On motion the report was accepted and ordered placed on file.

Mr. Vessy moved that the recommendation in the Treasurer's report in respect to the consolidation of accounts be approved. Motion seconded by Mr. Hageboeck and carried.

Mr. Patch moved that the further recommendations in the report be referred to the Finance Committee with power to act. Motion seconded by Mr. Vessy and carried.

Report of Technical Secretary

Technical Secretary Kennedy submitted a report on technical activities, including convention sessions, papers, transactions, and technical committee activities.

On motion the report was accepted and the Secretary was instructed to have copies prepared for all Directors that they might consider the recommendations made.

Executive Committee

No report was submitted as there had been no meetings of the committee held since the last Board meeting.

Report of Manager of Exhibits

In the report of the Manager of Exhibits covering the Philadelphia Convention it was stated that there were in all 239 exhibitors using a total of 75,238 square feet of space exclusive of aisles.

Mr. Vessy moved that the report be accepted and ordered placed on file. Motion Carried.

Apprentice Contests

In the report of apprentice contests it was stated that only one of the steel casting entries arrived in time, which left only the gray iron castings and the pattern contest entries to be judged.

The report of the judges of the gray iron molding contest gave the following as winners:

First place, Peter G. Bathgate, Brown & Sharpe Mfg. Co., Providence, R. I.

Second place, George A. Shuster, Jr., Olney Foundry Co., Philadelphia, Pa.

Third place, Attilio Rocchi, Cresson-Morris Co., Philadelphia, Pa.

The report of the judges of the pattern making contest gave the following as winners:

First place, Frank F. Cuzzone, General Electric Co., Schenectady, N. Y.

Second place, Arnold H. Behrens, Milwaukee Pattern & Mfg. Co., Milwaukee, Wis.

Third place, John Albert Anderson, John Deere Harvester Works, East Moline, Ill.

On motion the reports were accepted and the awarding of prizes and certificates authorized.

The Board then voted to award first prize for the apprentice steel molding contest to Alexander Cooke of the General Electric Co., Schenectady, N. Y., whose entry was the only one exhibited at the convention, and authorized the awarding of second and third prizes to the first and second place winners in the Milwaukee district contest.

The Directors recommended that the Apprentice Committee consider making arrangements to have all castings sent to the convention instead of having elimination contests in the various cities.

Obermayer Prize Contest

The Secretary read the report of the judges for the Obermayer Prize Contest, which stated that none of the entries submitted pertained to anything new or novel, or were of sufficient merit to warrant an award being made this year. The report recommended that future entries competing for this award be along lines pertaining to general foundry practice, rather than to auxiliary equipment, and suggested that each year the contest be limited to a certain phase of foundry practice, pattern mounting, etc.

Following discussion it was moved that the Committee on Apprentices be advised that in the opinion of the Board it was not advisable to limit the contests to certain phases of foundry practice. Plans were discussed for giving greater publicity to these contests and the Secretary was instructed to work with the Committee on Apprentices in putting them into effect.

A supplementary report of the judges was then read recommending that the A. F. A. conduct a contest each year in engineering schools having a recognized foundry course, to stimulate the interest of students in foundry practice and in the American Foundrymen's Association.

Following discussion it was moved that the report be accepted and laid on the table until the next meeting of the Board. Motion carried.

Educational Committee

Mr. Utley submitted a report outlining the objects and activities of the proposed Educational Committee, the appointment of which had been authorized at the meeting of the Board on May 13th. Before reading the report Mr. Utley said:

"This Association cannot become a trade association and cannot take on the functions of a trade association. Partially as a result of that stand, the Gray Iron Institute has been organized to do the things that the Malleable Iron Research Institute and the Steel Founders' Society are doing for their industries. It has been felt, however, that there are some things which the A. F. A. could do better than anyone else. I have felt that the A. F. A. ought to take some recognition of that feeling and not sit back and say we can have nothing to do with it."

Mr. Utley then read the following report:

The object of this committee shall be to orignate and disseminate to engineers and manufacturers, information tending to produce a "Castings Consciousness," i. e., a better realization of the value of the foundry industry and the possible use of castings of all kinds in manufacturing processes. Its function shall be *purely educational* and it shall not have as its direct object the merchandising of any particular kind of casting or the creating of a specific market for any material. It is designed to work with the various trade associations connected with the foundry industry, the State Foundrymen's Association and the Local Foundrymen's Association, coordinating their efforts along these lines wherever possible.

It is not intended that this committee shall use any paid advertising or operate in a manner which shall entail large expense to the Association. Its primary function shall be to act as a clearing house of information on uses of castings and on foundry matters which may be instructive and of interest to the engineering public, and to disseminate these through media already established. The following lines are suggested:

(a). Many foundries, equipment and supply manufacturers, and manufacturers of pig iron, coke, etc., are already large users of advertising space. In many cases these companies, if properly approached and supplied with proper information, would be glad to include in their space matters which would help to tell the story of the foundry industry.

(b). It is believed that articles can be gathered together telling of the designing of castings to take the place of fabricated parts, materially reducing machining and fabricating costs, and of other castings whose intricacy or size, or whose unusual use give them a real news value. These will be accepted and used in technical publications, and to some extent in the daily press, especially that of the locality where the foundry or designer resides. The gathering and dissemination of such literature, together with the enlisting of the cooperation and assistance of certain of the technical papers in this work, should be a function of this committee.

(c). There are numerous conferences held by engineering schools and by technical societies before which the foundry industry might well be represented. The committee should provide for such representation. It is not suggested, for the present at least, that the committee have one or more speakers who will travel all over the country attending these meetings, but rather that it arrange to have local representatives take care of them. Our office has the names of scores of able foundrymen and equipment men who have presided at sessions or given papers, who are competent to do such work. Suppose, for instance, that the Massachusetts Institute of Technology has an engineering conference on foundry practice or on welding practice or something of a similar nature. The Secretary of this committee would write to Mr. Jones and to Mr. Smith, members of the New England Foundrymen's Association, asking them to represent the committee by attending the sessions as an observer, to report on what was said and done (giving Mr. Jones and Mr. Smith an outline of the

items and form on which the report is desired, and also an outline which the committee would gradually build up of what had happened at other conferences). In a few years we should be able to hand any such men a mimeographed manual which would enable them to answer any question and to support any argument, and in addition we would be building up a force of our own members who could properly and adequately represent the industry under any conditions. We must remember that the flow of students through engineering schools is like the flow of the river; the volume may be apparently about the same, but the units are entirely new. In course of time the committee will doubtless find it possible to increase the number of conferences held by technical schools on purely foundry subjects.

(d). Arrange for such casting exhibits or exhibits of motion pictures of the foundry industry as may seem advisable. In many cases the trade associations may desire to handle these themselves, and the committee will have to work closely with them. This is a rather large subject and requires careful thought if the expense is not to be greater than the benefit to be derived.

(e). Impress upon the buying public that there is more to a casting than a certain number of pounds of metal, that the character of the foundry, its technical control, its engineering ability and the ability of its organization is of as vital interest as the fact that it has a cupola or a furnace. The greatest drawback to the success of the foundry industry today is the poor quality of the castings turned out by unprogressive units, and the fact that the buyer considers the product of the well-organized progressive foundry on the same plane as the others. The bringing of this realization to the purchasing public should make membership in the American Foundrymen's Association much more sought after.

This committee will report to the Executive Secretary and to the Board of Directors, and will come under its control. Its funds will be appropriated by the Board. Its policies will be outlined and directed by the Board, and it will continue from year to year only so long as the Board considers that its accomplishment justifies its existence.

Expense

The work of this committee will probably require the part-time services of some outside agency in gathering information which could be used by our present staff, and it may require the employment of additional help. The expense for the present, that is, until it has demonstrated whether or not it is of real value to the industry, and whether its work is capable of profitable enlargement, should consist of the fees paid the agency plus possibly additional help in the office, the expense of holding the meetings, some traveling expenses which under the scheme outlined should not be great, and some printing, all of which it is believed would not be an excessive burden to the Association.

Considerable discussion followed participated in by members of the Board and of the Advisory Board who were present, following which

it was moved that the report be accepted and Mr. Utley authorized to appoint a committee. Motion seconded and carried.

Adjourn for Lunch

At this point the meeting adjourned for lunch and following luncheon made a tour of the Stevens Hotel, inspecting the accommodations for meeting rooms and exhibits.

The meeting reconvened at 3:30 P. M. and before taking up the regular business Mr. John F. Bowman, Manager of Conventions and Exhibits of the Stevens Hotel, invited the Directors to consider the advantages that this hotel offered for holding an annual convention of the Association.

Recommendation of Committee on Cast Iron

The following recommendation of the Committee on Cast Iron adopted at a recent meeting held at Atlantic City was read:

Your Committee on Cast Iron is agreed that before a comprehensive program of research on cast iron can be adequately advanced, there should be made available a summary of the existing information on cast iron.

This is the logical next step to follow the previous activity of the A. F. A. in preparing a bibliography of available information on cast iron. To do this job adequately, at least $25,000 would be required. The A. F. A. and the Gray Iron Institute are the logical bodies to handle this job.

However, the Engineering Foundation has recently embarked on a larger project, the preparation of a summary of available information on alloys of iron, which would cover both iron and steel, with a two year program estimated to cost $100,000. For this purpose the Engineering Foundation has appropriated $10,000 as a nucleus, and is in process of raising the balance from the various fields covered by the whole project. The Engineering Foundation has expressed its intention to give cast iron the proportion of attention demanded by its importance as an engineering material.

Your committee is inclined to favor some reasonable form of cooperation with the Engineering Foundation in this project, and would recommend that the Board appropriate $5,000 to initiate this joint project—provided the conditions of cooperation between the A. F. A. and the E. F. are satisfactory to the A. F. A. If this would prove not to be the case, the committee points out that the A. F. A. would be asked to raise the whole sum (at least $25,000) for this work.

As it was expected that if this work was undertaken the newly organized Gray Iron Institute would cooperate, Mr. D. M. Avey, temporary Secretary of the Institute, was present on invitation of the Board and took part in the discussion of the report and recommendations of the A. F. A. committee.

Following discussion it was voted that the report be accepted and referred to a committee of three to be appointed by the President, this committee to obtain further information as to the plan of the Engineering

Foundation, confer with the Committee on Gray Iron Castings, and report back to the Board or to the Executive Committee.

Committee on Research

It was moved by Mr. Patch that the President appoint a committee of five, to represent the various branches of the industry, to determine the policies of the Association regarding research and appropriations for that purpose. Motion carried.

U. S. Survey of Apprentice Statistics

The Secretary read the following resolution adopted at the Apprentice Session of the Philadelphia Convention, read at the adjourned annual business meeting, and referred to the Board of Directors:

Whereas, the work of training young men for the foundry industry and for industry in general is seriously handicapped by a lack of information as to the number of young men and boys who are employed as apprentices in the various industries, and

Whereas, the biennial census of manufactures of the United States constitutes an excellent medium already existing for the gathering of such information,

Therefore be it Resolved, that the American Foundrymen's Association, through its board of Directors, petition the United States Government to include statistics in its biennial census of manufactures regarding the total number of young men being trained in the various industries by formal or indentured apprenticeship and the proportion which this number bears to the number of skilled mechanics.

It was moved that the Board take action in accordance with the resolution. Motion carried.

Resolution on Proposed Steel Casting Specifications

The resolution adopted at the Steel Founding Session at the Philadelphia Convention on May 16th concerning proposed A. S. T. M. Specifications A-95, Alloy Steel Castings for High Temperature Service, was read by the Secretary, who stated, that at the session when the resolution was submitted there were only 26 persons present and only 16 voted.

It was the consensus of opinion that the attendance at this meeting was not sufficiently representative of the members interested in these specifications to justify action by the Board, and it was therefore moved that the report be laid on the table. Motion carried.

Recommendations of Cost Committee

The Secretary read the following recommendations of the A. F. A. Cost Committee, which were approved at the Cost Session at the Philadelphia Convention and referred to the Board of Directors for approval:

1. Recognition by the A. F. A. of the uniform cost system of the Steel Founders' Society of America and recommendation of its use in all steel foundries.

2. Recognition by the A. F. A. of the uniform cost system of the Malleable Iron Research Institute and recommendation of its use in all malleable foundries.

3. That the A. F. A. encourage the Gray Iron Institute to devolop a uniform cost system for gray iron foundries.

4. That the A. F. A. encourage the organization of a representative group of non-ferrous foundries for the purpose of developing a uniform cost system for non-ferrous foundries.

The report stated further that the committee believed it would be advisable for the American Foundrymen's Association not to deal with the details of cost accounting practice, as these can best be handled by the individual branches of the foundry industry as recommended in the foregoing. Therefore, it was the opinion of the committee that the A. F. A. should confine its activities to educational work along the lines of cost accounting and the application of such to merchandising and manufacturing.

On motion duly seconded the report of the committee was accepted and approved.

Recommendations of Joint Committee on Molding Sand Research

Technical Secretary Kennedy, for the Committee on Molding Sand Research, requested approval of the Directors to issue a publication containing revised standard and tentative standard procedures for testing sands, this publication to be followed by one containing non-standard procedures for shop control work, to be issued for the benefit of the industry at large as they considered that the development of control methods would ultimately assist in devising more simple and practical standard methods.

Mr. Ballard commenting on the fine work done during past years by this committee moved that the Board adopt their recommendations and authorize the publication of a new pamphlet on molding sand tests. Motion carried.

Malleable Foundry Refractory Standards

The Board gave its approval to the Tentative Standard Malleable Foundry Refractories shapes and sizes adopted by the Joint Committee on Foundry Refractories, which were presented at the 1927 convention, and accepted without revision at a conference called by the Division of Simplified Practice of the Department of Commerce of the U. S.

On motion duly seconded these standards were approved.

Resignation of W. D. Goldsmith

The Secretary read a letter dated June 22nd from W. D. Goldsmith requesting that his resignation be presented to the Board of Directors, as his private affairs were giving him more to do than he could properly attend to. On motion by Mr. Vessy duly seconded, the resignation was accepted.

Uniform Trade Customs for the Casting Industry

The Secretary reported that requests had been received from a number of sources that the Association sponsor the appointment of a joint committee to draft uniform trade customs for the casting industry. Letters were read on this subject, including some from the secretaries of the Malleable

Iron Research Institute, Steel Founders' Society of America, and the Ohio State Foundrymen's Association.

It was moved that a committee of three be appointed by the President to consider the advisability of sponsoring a joint committee and report back to the Board. Motion carried.

Approval of Acts of Committees of the Board

Mr. Erb moved that the Board approve all acts of committees of the Board during the year. Motion carried.

Report of Election of Officers and Directors

The Secretary reported that at the annual business meeting of the Association held at the Bellevue-Stratford Hotel, Tuesday, May 15, 1928, the election of the following officers and directors was confirmed: for President to serve for one year, S. T. Johnston; for Vice-President to serve for one year, Fred Erb; and for Directors to serve for three years, P. J. Krentz, B. H. Johnson, L. W. Olson, S. W. Utley and C. E. Hoyt.

Honorary Member

The Secretary reported that at the annual business meeting of the Association on May 15th retiring President Stuart Wells Utley was unanimously elected to Honorary Membership.

Appreciation

Mr. Patch moved that a vote of appreciation be given retiring Directors Jesse L. Jones and Herbert S. Simpson for their faithful service as Directors and their interest in all matters having to do with the advancement of the American Foundrymen's Association, and that the Secretary be instructed to convey this expression of the Board to them. The motion was seconded and unanimously carried.

Mr. Hoyt stated that it was his pleasure to move that suitable resolutions be prepared expressing the appreciation of the Board to Stuart Wells Utley for the efficient and faithful service rendered during his two terms as President of the American Foundrymen's Association. The motion was seconded, put to the board by the Secretary and unanimously carried.

Adjournment

Mr. Utley: "That concludes the work of this Board and before asking for a motion to adjourn, I want to thank each and every one of you for the cooperation and help I have received and for the splendid fellowship which we have all had. It has been a joy to work for the Association and to work with the Secretary, and I want to assure you that in many ways I step out of this job with a great deal of regret. On the other hand there are many reasons why I am happy to turn it over to such a worthy man as Sam Johnston."

On motion by Mr. Olson duly seconded the meeting adjourned and Mr. Utley turned the gavel over to the incoming President S. T. Johnston.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. W. Utley, President.

Minutes of First Meeting 1928-29 Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

THE STEVENS HOTEL, CHICAGO, ILL.,
MONDAY, JULY 16, 1928.

Accepting the gavel from President Utley and calling the meeting of the Board to order, Mr. Johnston said that he felt it was the supreme moment of his business life to occupy the chair as President of the American Foundrymen's Association after having occupied practically every other position around the Board table, that he realized fully the responsibilities that were his in taking up the duties that had been so well performed by able predecessors, but that with the support and cooperation of the members of the Board he would hope for a successful and prosperous year for the Association and its members.

Roll Call

The following responded to roll call: President S. T. Johnston, Vice-President Fred Erb, Technical Secretary R. E. Kennedy, and Directors, N. K. B. Patch, S. C. Vessy, L. C. Wilson, E. H. Ballard, A. E. Hageboeck, B. H. Johnson, P. J. Krentz, L. W. Olson, S. W. Utley and C. E. Hoyt.

Past presidents R. A. Bull, B. D. Fuller and H. D. Miles were also present.

Organization of New Board

On motion the Chair was instructed to appoint a committee of three to nominate officers and Executive Committee members, also someone to fill the vacancy on the Board caused by the resignation of W. D. Goldsmith. The Chair appointed S. W. Utley, L. C. Wilson and B. H. Johnson.

Report of Nominating Committee

Mr. Utley reported for the Nominating Committee as follows:

For the combined offices of Executive Secretary, Treasurer and Manager of Exhibits we nominate C. E. Hoyt.

For the office of Technical Secretary we nominate R. E. Kennedy.

In selecting four members of the Executive Committee to serve with the President, Vice-President and Executive Secretary, we were advised that precedent made it incumbent upon us to nominate the junior past president. We therefore submit the names of S. W. Utley, A. B. Root, Jr., S. C. Vessy and A. E. Hageboeck.

The Chair called for further nominations. There being none, it was moved that the Chair be instructed to cast the ballot for the nominees as named by the committee. Motion prevailed, whereupon the Chair announced that the unanimous ballot of the Board had been cast and declared all candidates elected to the respective offices and committee for which they had been named.

Mr. Utley then stated that to fill the unexpired term of Mr. Goldsmith, resigned, the committee submitted the name of H. Cole Estep, of the Penton Publishing Co., and for many years chairman of the A. F. A. Committee on International Relations.

There being no further nominations, the Secretary was instructed to cast the ballot of the Board and H. Cole Estep was declared unanimously elected to fill the vacancy caused by the resignation of Mr. Goldsmith.

Report of Finance Committee

Mr. Utley reporting for the Finance Committee stated, "The Finance Committee has only one recommendation to make at this time. Ordinarily this is a matter that would come up at the end of the year, but as you were told this morning, Technical Secretary Kennedy will move his office from Urbana to Chicago some time in August. This will mean a decided increase in efficiency in handling of the work, but an increase in expense for Mr. Kennedy. We therefore unanimously recommend that beginning July 1st, Mr. Kennedy's salary be increased from $400.00 to $500.00 per month."

On motion the report of the committee was received and the recommendation approved.

Disbursement of Funds

Resolved, That checks for the withdrawal of funds deposited in the name of the Association in the Harris Trust & Savings Bank, and Chicago Trust Co., Chicago, be signed by President S. T. Johnston or Secretary-Treasurer C. E. Hoyt, and countersigned by President S. T. Johnston or Vice-President Fred Erb.

Be It Further Resolved, That the resolutions required by the aforementioned banks authorizing the withdrawal of funds of the Association in accordance with the above resolution are hereby approved and adopted.

Be It Further Resolved, That the officers of the Association are hereby authorized to open an account in the convention city for a special convention fund, they to determine how this account shall be opened and the signatures required for the withdrawal of said fund.

Be It Further Resolved, That the Board authorize a Secretary-Manager's petty cash fund of $500.00, said fund to be reconciled at the end of each month by a full statement of expenditures.

Be It Further Resolved, That the President and Executive Secretary are authorized to employ such assistance as is found necessary to take care

of Association activities, compensations for such services to be approved by the Finance Committee.

On motion by Mr. Vessy duly seconded the above resolutions were unanimously adopted.

Treasurer's Bond

On motion the bond of the Treasurer was continued and payment of premium authorized.

Auditing of Books

The President was authorized to engage an auditor to audit the books for the year ending December 31, 1928.

Committee Meeting Expense

On motion duly seconded the Treasurer was authorized to reimburse Directors for expense of attendance at Board meetings and committee members for traveling expenses to any authorized committee meetings, except for attendance at Board or committee meetings held at the place and during the week of the annual convention of the Association.

Committee Appointments

On motion the President was authorized to make all appointments for standing and special committees not provided for in the By-Laws or by special act of the Board.

Depreciation Rates

A communication was read from the Department of Internal Revenue on the subject of Outline for the Study of Depreciation and Maintenance, extending an invitation to the A. F. A. to join with other foundry organizations in a study of depreciation for foundries.

On motion the Secretary was instructed to reply that the A. F. A., not being a trade association, could not consistently participate in this work, and to further advise that a large number of the members of A. F. A. were members of trade associations representing the different groups of casting manufacturers and through them would have representation.

1929 Nominating Committee

On motion the President was instructed to appoint a committee of three to select ten members whose names would appear on a letter ballot for election by the members of four members of the 1929 Nominating Committee.

Authority of Executive Committee

On motion the Executive Committee was empowered to act for the Board in the interim between Board meetings on all matters requiring Board action.

1929 Convention

The Secretary read a letter which had been sent by President Utley to the Directors outlining various plans that had been suggested for the 1929 annual convention.

Following discussion the Board voted unanimously to approve suggestion No. 6 and to hold the 1929 Convention during the month of March or April, 1929, and subject to satisfactory negotiations being consummated, that the Convention be held at the Stevens Hotel, Chicago, with a limited exhibit to be located in the Exhibition Hall of the hotel. The motion included instructions to the Executive Committee to negotiate with the management of the Public Auditorium, Cleveland, Ohio, for a Convention and unlimited exhibit in the spring of 1930.

Dues for Members

On motion the Secretary was authorized to prorate the dues of new members secured following the annual convention of each year on a monthly basis and to make members elected during November and December members in good standing to December 31st of the following year on payment of one full year's dues.

Minimum Standards of Four-Year Foundry Apprenticeship

The Secretary read a recommendation of the Committee on Training of Apprentices that the Association endorse the Minimum Standards of Four-Year Foundry Apprenticeship as outlined in a pamphlet published by the National Founders' Association.

On motion the recommendation was received and action deferred until the next meeting of the Board, and the Secretary instructed to secure copies of the pamphlet for each Director.

Castings Exhibit

A report of the castings exhibit at the Philadelphia Convention was presented, following which the Board went on record as approving a similar exhibit at the 1929 Convention if, in the judgment of the Executive Committee, satisfactory arrangements could be made.

Adjournment

On motion by Mr. Olson, duly seconded, the meeting stood adjourned.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. T. Johnston, President.

Testing Molding Sands for Durability

By M. A. Blakey*, Milwaukee, Wis.

When a new brand of molding sand is delivered to the foundry for trial, it is not always practical to cast in it without first mixing with used sand of a different brand. The results obtained from such a mixture may be very different from those which might have been obtained if the new sand had been mixed with used sand of the same brand. Therefore, to develop conclusive facts from such a test, it would be necessary to continue it long enough for the new brand to replace the old in the heap. It takes both patience and time to do this, and faulty conclusions are frequently the result of such tests, as sufficient time is usually not taken.

For approximately a year at the Milwaukee Works of the International Harvester Company we have been using a laboratory test for observing the characteristics of molding sands and molding sand bonds when subjected to the action of molten iron under conditions approximating those in the foundry.

In Figs. 1 and 2 is shown the apparatus used for this purpose in conjunction with the standard A. F. A. bond strength and permeability testing equipment, and in making this test a small simple mold is made in the laboratory, taken into the foundry and poured with our regular iron from a hot hand ladle. This is repeated several times on each sample of sand, but before each cast the bond strength and permeability are determined.

*International Harvester Company.

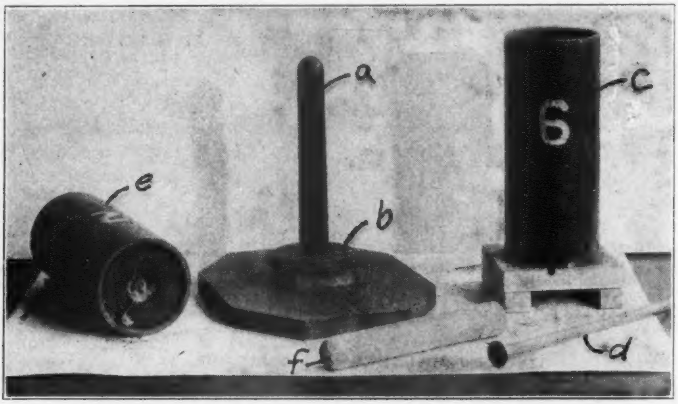


FIG. 1—SPECIAL EQUIPMENT USED IN DURABILITY TESTS—*A*, PATTERN; *B*, STRIPPER PLATE; *C*, FLASK ON BOTTOM BOARD; *D*, RAMMER; *E*, MOLD READY FOR SHAKING OUT; *F*, CASTING MADE IN TEST MOLD

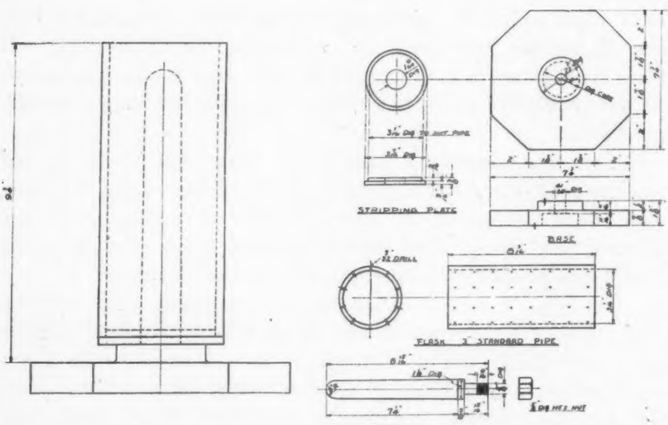


FIG. 2—PATTERN AND FLASK FOR SAND DURABILITY TEST

Procedure

A 2000 gram sample of sand is used for this test. Its optimum water content is first determined and then it is retempered with the moisture content most suitable for molding. As the optimum water content of most sands changes with use, it is not necessary or always desirable to cast at this moisture.

After the per cent of moisture desired has been added, the sample is allowed to temper for twenty-four hours in a sealed two quart mason fruit jar. The bond strength, permeability and moisture content are then determined and the mold is rammed and poured. As only about 1300 grams are required for the mold, the remainder of the sample is returned to the sealed jar so that it will not dry out.

After pouring, the casting is left in the mold until it is cold enough to hold in the hand. It is then shaken out, a stiff bristle brush being used to brush the sand from the casting.

The sand from the mold, having been thoroughly dried by the heat from the casting, is weighed and retempered to the original moisture content. It is then thoroughly mixed with the unused portion of the sample and again sealed in the jar for a period of not less than twenty hours. It is then tested for bond strength, permeability and moisture content, and a second cast is made. This procedure is repeated for as many casts as are desired. After the last cast is made, the sample is tested for its optimum water content.

The bond strength and permeabilities at the optimum water content at the beginning and end of the test are indicative of the durability of the sand and may be expressed in percentages.

In accordance with standard practice the sample should be sealed in the jar with its moisture for at least twenty-four hours before being tested for bond strength and permeability. If this practice is adhered to, a cast every second day only may be made, and it will require proportionately longer to make the test. It has, therefore, been our practice to cast once daily, allowing as much tempering time as possible between casts. However, before testing the sand after the final cast, we have allowed the sand at least twenty-four hours in which to develop its maximum bond. If we were interested only in the characteristics of the

sand at the beginning and end of the test, two casts per day could be made by shortening the tempering time.

In order to test clay bonds by this method, it is necessary to make up a synthetic sand, using the bond to be tested and a standard sand. Our standard sand is a bank core sand with a small amount of bond. We selected this sand on the assumption that our laboratory tests would then approach nearer to our practice should we ever make our molding sand from new sands and clay bonds. On the other hand, a steel foundry in making similar tests might for the same reason prefer to use a sand free from bond.

In making synthetic sands for these tests, we have attempted to get a bond strength between 200 and 250 at the beginning of the test, this bond strength being at the moisture at which molding is done.

Table 1

BOND STRENGTH AND PERMEABILITY OF STANDARD SAND AT VARIOUS WATER CONTENTS

Per Cent Water	1	2	3	4	5	6
Bond Strength	78	78	84	97	91	89
Permeability	88	99	99	96	90	88

Before preparing the sample, a preliminary test is made to determine the approximate amount of bond and water which will be required. The sand, bond and water are then weighed or measured out and about one-third of the water is added to the sand and thoroughly worked in by rubbing between the hands. A portion of the bond is then added and the mixture worked between the hands until uniform. In this way the bond and water are added alternately until all is in, care being taken not to get the mixture too wet or too dry.

The above practice in bonding sands is different from that usually recommended, and may be questioned by some. However, tests show conclusively that less bond is required for a given strength than when the sand and bond are mixed dry. This difference is especially noticeable where the bond is ground fine, as the bond becomes lumped and separated from the sand grain when the water is added last.

After the synthetic sand is made, it is tested in the same way as a natural sand.

Durability Test Yields Other Information

Although our original purpose in making these tests was to determine the relative effect of use on the bond strength and permeability, we soon found that other information obtained through them was of equal or greater importance. Examination of the castings made during the test indicate quite well what we can expect from the foundry if a particular sand is used. Some sands burn on and some peel nicely, some give a smooth finish and some a rough finish, some cut and scab easily and some do not and some shake out of the mold with little effort, while others become as hard as a dry sand core.

We have not attempted to record all of the information obtained with this test as definite measures for these properties are not available. Nevertheless, all of this information has been of practical value in the selection of our molding sands.

Results of Tests on Natural Sands

When these tests were first started, it was expected that five casts would show the characteristics of a sand quite well and for the natural molding sands, they have done so. These tests were therefore made with a 1500 gram sample and all tests of natural sands reported here were so made.

However, when tests on synthetic sands were attempted, it was found that at least ten casts were necessary as the durability of the synthetic sand was much greater. As a 1500 gram sample would not permit ten casts, the 2000 gram sample was then taken as our standard.

Figs. 3 to 8, inclusive, show the results of durability tests made on eighteen of the natural sands which we tested. Only bond strength and permeability are shown, the bond strength being indicated by the solid black column and the permeability by the cross hatched column. The pair of columns indicated by the letter "N" show these properties of the new sand and the pair marked "1 C" these properties of the sand after the first cast.

Most of these sands were tested at a water content of 6 per cent, the only exceptions being samples Nos. 9 and 25, Fig. 7, which were tested at 7 per cent and 5 per cent respectively.

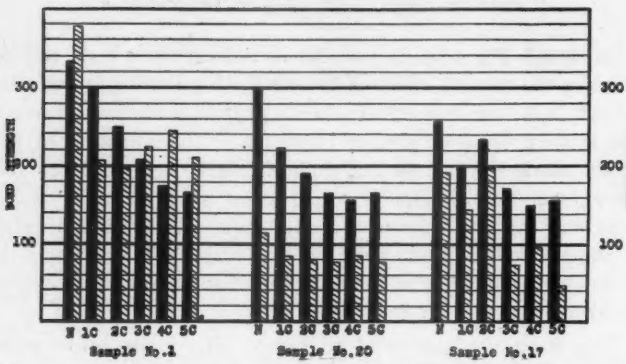


FIG. 3—WISCONSIN AND INDIANA SANDS—SANDS FROM WHICH SAMPLES NOS. 1 AND 20 WERE TAKEN ARE PRODUCED IN WISCONSIN AND HAVE BEEN USED VERY SUCCESSFULLY IN OUR FOUNDRY. NO. 1 IS WELL KNOWN AND EXTENSIVELY USED; IT IS ROUGH AND GRAVELLY, BUT PRODUCES A SMOOTH CASTING SURFACE. NO. 20 IS NOT GENERALLY KNOWN, BUT WOULD BE AN UNUSUALLY GOOD SAND IF THE DEPOSIT WERE MORE UNIFORM. NO. 1 IS NOT INJURED BY WET WEATHER WHEN SHIPPED IN OPEN CARS AND NO. 20 BUT SLIGHTLY SO

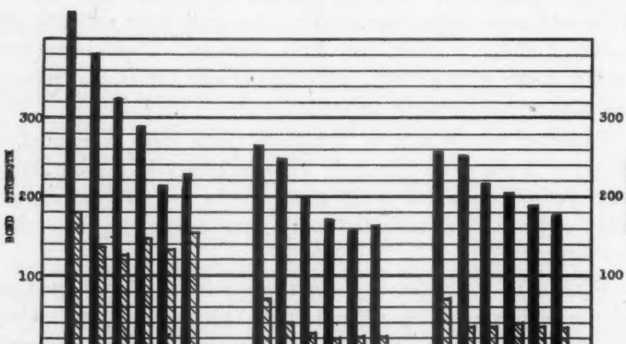


FIG. 4—ILLINOIS SANDS—THE SAND FROM WHICH SAMPLE NO. 21 WAS TAKEN WAS TRIED IN OUR FOUNDRY AND REJECTED BEFORE A DURABILITY TEST WAS MADE. IT WAS FELT AT THAT TIME THAT WE HAD MADE A MISTAKE IN SELECTING SUCH A CLOSE SAND. THE DURABILITY TEST SHOWED THAT THE DIFFICULTY CAME THROUGH THE LOSS OF PERMEABILITY AFTER USE. NO. 8 WAS NOT USED FOR THIS REASON AND BECAUSE IF RAINED ON IN TRANSIT IT WOULD HAVE BEEN DAMAGED. NO. 8 WAS ONLY TESTED TO SEE HOW A VERY STRONG SAND WOULD BEHAVE, AS THE FREIGHT RATE AMONG OTHER THINGS WAS AGAINST ITS USE

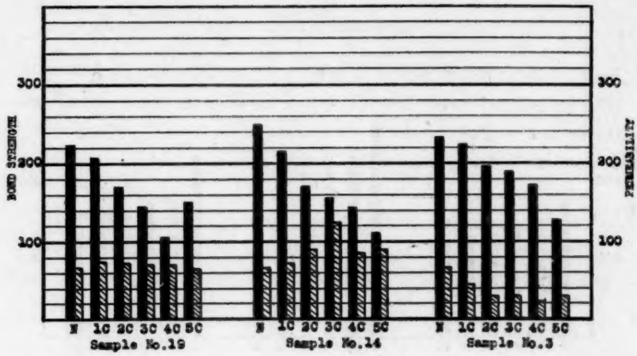


FIG. 5—WISCONSIN SANDS—SAMPLES NO. 19 AND 14 WERE BEING GIVEN FAVORABLE CONSIDERATION UNTIL AN INSPECTION OF THE PITS CONVINCED US THAT A UNIFORM PRODUCT WAS HARDLY PROBABLE. IF SAMPLE NO. 3 HAD NOT LOST ITS PERMEABILITY, IT WOULD HAVE BEEN CONSIDERED VERY PROMISING AND A PIT INSPECTION WOULD HAVE BEEN MADE

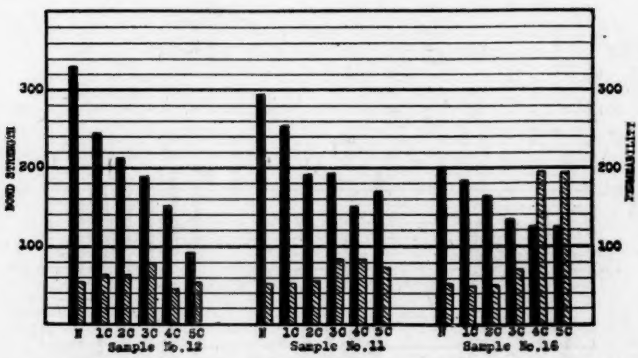


FIG. 6—WISCONSIN, ILLINOIS AND OHIO SANDS—SAMPLES NO. 11 AND 12 WERE REJECTED THROUGH DANGER OF DAMAGE FROM RAIN WHILE IN TRANSIT. THE FREIGHT RATE ON NO. 16 INFLUENCED US AGAINST IT, ALTHOUGH THE EXCESSIVE PERMEABILITY AFTER THE FOURTH AND FIFTH CASTS AND THE APPEARANCE OF THE CASTING INDICATED THAT IT WAS NOT ENTIRELY SUITABLE

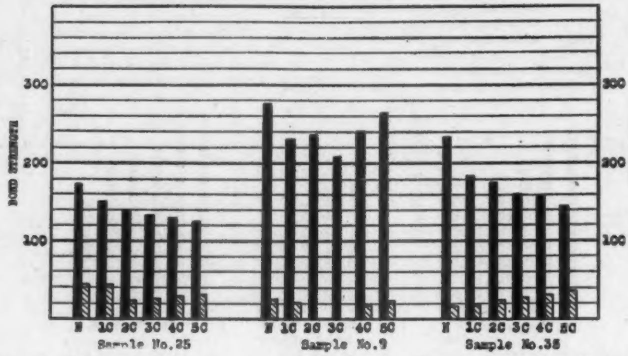


FIG. 7—ILLINOIS, OHIO AND NEW YORK SANDS—SAMPLE NO. 35 IS NO.-1-ALBANY, NO. 9 COMES FROM OHIO AND RETAINS ITS BOND STRENGTH BETTER THAN ANY OTHER NATURAL SAND TESTED. THE PERMEABILITY AFTER THE SECOND AND THIRD CAST WAS OMITTED BY ACCIDENT. NO. 25 IS TOO WEAK TO MAINTAIN THE BOND STRENGTH DESIRED IN THE HEAP

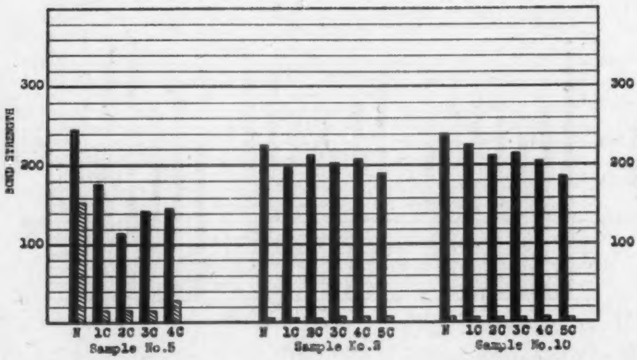


FIG. 8—WISCONSIN AND INDIANA SANDS—THE SAND FROM WHICH SAMPLE NO. 5 WAS TAKEN HAS BEEN USED IN OUR FOUNDRY FOR BENCH WORK SINCE BEFORE WE BEGAN TESTING FOR DURABILITY. THIS HAS PROVED TO BE A VERY SATISFACTORY SAND. NOS. 2 AND 10 ARE LOW IN PERMEABILITY AND SUBJECT TO DAMAGE BY RAIN IF SHIPPED IN OPEN CARS

Results of Tests on Commercial Clay Bonds

Of the five bonds listed in Table 2, Samples Nos. 27 and 32 are colloidal clays and 28, 30 and 31 are clays produced east of the Mississippi River. All are well known commercial molding sand bonds. Three of these, Nos. 30, 31 and 32, have been used in our foundry.

These bonds were tested for durability by our present standard methods, which makes use of a 2000 gram sample. The results of these tests are shown in Table 2 and Figs. 9, 10 and 11.

Table 2

DURABILITY TESTS ON SYNTHETIC SANDS BONDED WITH COMMERCIAL CLAY BONDS

Sample Number	Per Cent Bond Used		Test for Optimum Water Content: Per Cent Water	2	3	4	5	6	Per Cent Bond Loss at Max. Perm.	Per Cent Permeability Change	Per Cent Water When Casting
27	5.5	Before Casting	Bond Strength	287	290	240	221	203	49	17*	4
			Permeability	75	108	99	82	75			
		After Casting No. 10	Bond Strength	131	147	127	119	...			
			Permeability	115	126	115	105	...			
28	17	Before Casting	Bond Strength	146	277	252	232	217	30	14*	4
			Permeability	52	63	63	70	65			
		After Casting No. 10	Bond Strength	...	123	155	162	127			
			Permeability	...	61	72	80	75			
30	26	Before Casting	Bond Strength	...	196	222	214	202	28	23*	5
			Permeability	...	36	40	47	42			
		After Casting No. 10	Bond Strength	...	...	128	154	142			
			Permeability	...	...	49	58	52			
31	19	Before Casting	Bond Strength	...	226	215	192	177	29	20†	4.5
			Permeability	...	73	88	77	75			
		After Casting No. 10	Bond Strength	...	160	152	128	112			
			Permeability	...	65	70	70	67			
32	5.5	Before Casting	Bond Strength	294	250	236	218	197	42	NONE	4
			Permeability	85	88	108	90	85			
		After Casting No. 10	Bond Strength	185	156	137	134	131			
			Permeability	88	96	108	99	90			

*Increase †Decrease.

Synthetic sands made from these bonds show a marked difference in other characteristics as well as in bonding power and durability. Fig. 12 shows the appearance of the sands after they are shaken out of the laboratory mold. It is not difficult to picture the wear and tear on flask equipment which would result from the use of No. 32 as compared with No. 30. It is also

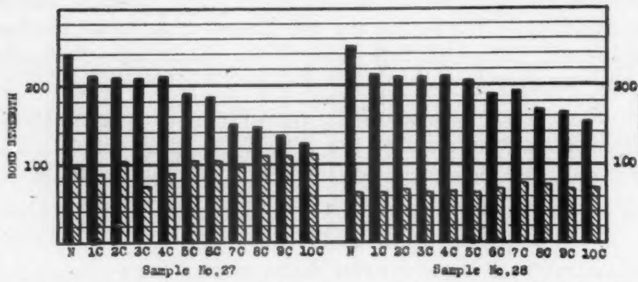


FIG. 9—SYNTHETIC SANDS BONDED WITH COMMERCIAL CLAY BONDS—SAMPLE NO. 27 WAS TESTED AT A WATER CONTENT 1% HIGHER THAN THE OPTIMUM, AND NO. 28 AT A WATER CONTENT 1% LOWER. THE WATER CONTENT AFTER THE FIRST CAST ON EACH WAS LOW, AND HIGH AFTER THE SECOND CAST ON NO. 28

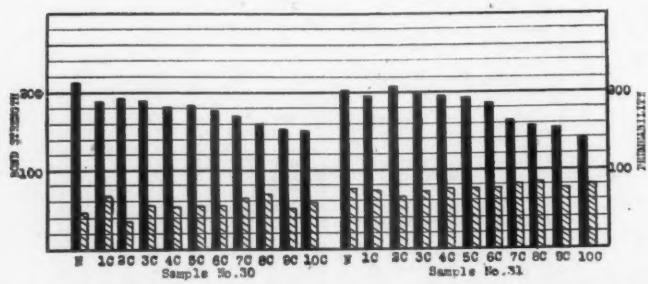


FIG. 10—SYNTHETIC SANDS BONDED WITH COMMERCIAL CLAY BONDS—SAMPLE NO. 30 WAS TESTED AT THE OPTIMUM WATER CONTENT AND NO. 31 AT 1% ABOVE. THE WATER CONTENT AFTER THE FIRST THREE CASTS ON NO. 30 AND FIRST CAST ON NO. 31 WAS LOW

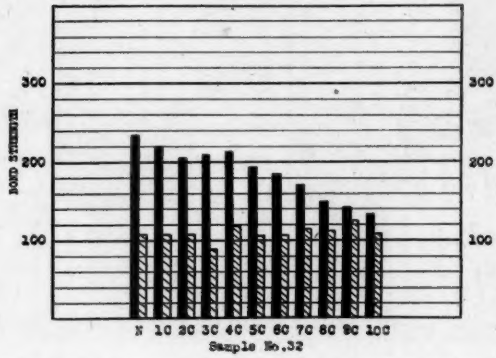


FIG. 11—SYNTHETIC SAND BONDED WITH A COMMERCIAL CLAY BOND—THIS SAND WAS TESTED AT A WATER CONTENT 1% ABOVE THE OPTIMUM. THE WATER CONTENT AFTER THE FIRST CAST WAS LOW AND HIGH AFTER THE THIRD

FIG. 12—SYNTHETIC SANDS AS THEY APPEARED AFTER BEING SHAKEN OUT OF THE TEST MOLDS—SAMPLES 28, 30, AND 31 HAD BEEN CAST IN FIVE TIMES, AND 27 AND 32 SIX TIMES. THE DIFFICULTY EXPERIENCED IN SHAKING OUT EACH SAMPLE IS INDICATED BY THE LUMPINESS. NONE OF THE ABOVE SAMPLES CHANGED MUCH IN THEIR TENDENCY TO LUMP AS THE TEST PROGRESSED

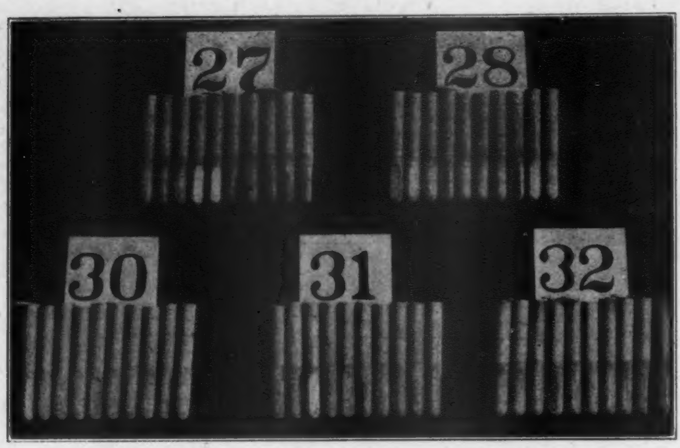


FIG. 13—TEST CASTINGS MADE IN SYNTHETIC SANDS—THE UPPER HALF OF EACH CASTING HAS BEEN CLEANED BY BLASTING AND THE POOREST SIDE OF EACH HAS BEEN TURNED TOWARDS THE CAMERA

evident that a casting made with a green sand core from No. 30 would have a better chance of getting past the core knockout crew without being broken than if No. 32 had been used.

It was attempted with rather poor results in Fig. 13 to show the difference in the castings produced in these sands. Nos. 27 and 32 produced smoother castings and showed less tendency to cut or scab. Castings from No. 31 were the poorest in these respects.

It should not be inferred from Fig. 13 that the synthetic sands show a greater tendency to cut and scab than do the natural sands. It is readily seen that this is a very severe test in view of the fact that in pouring, the stream of iron tends to strike one wall of the mold and cutting and scabbing are very apt to occur.

In ease of cleaning and tendency to peel, Nos. 28, 30 and 31 are better than 27 and 32.

Heat Losses from a 75-Ton Hot Metal Car[1]

By Wm. F. Roeser[2], Washington, D. C.

For many years it has been the practice in the iron and steel industries to transport molten metal from one location or furnace to another in open ladles. Recently a closed type hot metal car has been introduced. The only opening in this car is at the top and is only about three feet in diameter so that the heat loss from the free surface is much less than from the open ladle. In the use of these cars it is occasionally necessary to hold the molten metal in the cars for many hours and consequently a knowledge of the rate of cooling is of great value in determining the length of time that the metal can be held in the car without freezing. At the request of the American Foundrymen's Association tests were undertaken during March, 1927, to make the necessary temperature measurements for determining the cooling rate of the iron in the car, the loss of heat from the surface of the car by radiation and convection and the amount of heat conducted through the lining.

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[1] Published by permission of the Director, Bureau of Standards, Washington, D. C.
[2] Consulting Physicist, Bureau of Standards.

The type of car tested is shown in Fig. 1. For the purpose of the measurements its surface was laid off into seven circumferential portions lettered successively from A to G beginning at one end. The A and G portions were the trunnion castings on each end. The B and F portions were the two conical portions between the trunnion castings and the cylindrical middle portion. The portions C, D and E were on the cylindrical portion with the center line of the D portion dividing the car in halves. The surface was then laid off into five longitudinal portions, numbered successively from 1 to 5. The center lines of portions 1 and 3 divided the car into upper and lower halves. Portion 2 was on the

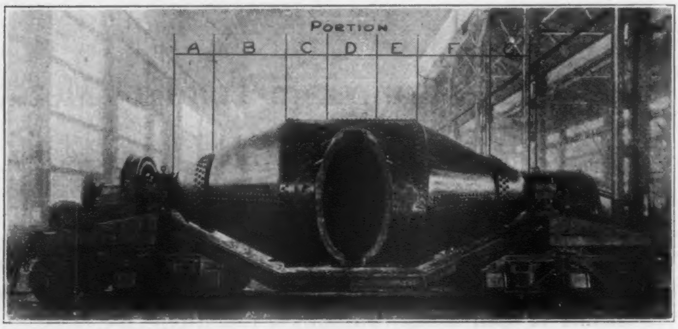

FIG. 1 CAR AND LADLE USED IN TEST

top of the car and since the riveted butt straps and ladder located on the top made it impossible to take readings directly on top, two sets of readings were taken, one on each side of the butt strap or ladder. Portions 4 and 5 were at the bottom of the car, one portion on each side, as it was impossible to obtain readings directly on the bottom.

All temperature measurements on the molten metal were made with a platinum to platinum-rhodium thermocouple protected by porcelain and graphite tubes, except a few measurements on the metal in the runner with an optical pyrometer. All the temperature measurements on the external surface of the car were made with a contact pyrometer designed by the Bureau of Standards.

At four points on the surface, chromel-alumel thermocouples were peened in for the purpose of checking the contact pyrometer.

An attempt was made to obtain the temperature drop of the metal in the runner. The length of the runner from the blast furnace to the slag dam was eighteen feet and from the dam to the car was 55 feet. Temperature measurements were made at the dam and at the end of the runner as the metal entered the car, but the temperature varied greatly with the rate of flow. The temperature readings at the dam varied as much as 60 degrees Cent. while the car was being filled. At the car the temperature of the metal varied as much as 80 degrees depending largely upon the rate of flow. Under such conditions it is impossible to state the magnitude of the temperature drop in the runner, but the average of all the readings taken at these points over the same time interval is given in this report.

The car, after weighing, was located at blast furnace No. 11 of the Franklin Plant at the Cambria Works of the Bethlehem Steel Co. Before the car was filled, the surface temperatures were measured with the contact pyrometer and the inside surface temperature measured with an optical pyrometer. The test car was the second of three filled from this blast furnace. After filling the car, it was again weighed and removed to the ladle house where the remaining temperature measurements were made. Portions 3 and 4 of the car were cooled somewhat by a breeze blowing through some open windows and striking the side of the car.

The data of Table 1 were supplied by the Treadwell Company and the Bethlehem Steel Company.

Table 2 gives the temperatures of the metal before entering the car and for each successive hour after the car was half-filled. The time required to fill the car was 12 minutes. The car was placed in the ladle house 35 minutes after being filled.

Table 3 gives the cooling rate for the molten metal for each hour after filling the car. The high initial drop in temperature is due to the fact that a great amount of heat is required for the initial heating of the lining. The cooling rate for the first hour is derived from the average temperature of the metal entering the car.

Table 1

DATA OF CAR AND LADLE

Original light weight of car with lining	194,700	lbs.
Shipping weight of car without lining	131,900	lbs.
Net weight of lining new	62,800	lbs.
Light weight of car March 4th before test began	189,300	lbs.
Loss in weight of lining up to time of test	5,400	lbs.
Weight of lining in car at time of test	57,400	lbs.
Total weight of metal parts of car shell including rivets, butt straps, trunnions, trunnion bearings and spout casting	47,200	lbs.
Gross weight of car after filling	333,100	lbs.
Light weight of car before filling	189,300	lbs.
Weight of molten iron contents	143,800	lbs.
Surface area of each trunnion casting	32.32	sq. ft.
Surface area of each conical portion	99.04	sq. ft.
Surface area of cylindrical portion	186.63	sq. ft.
Surface area of each trunnion bearing	19.66	sq. ft.
Surface area of spout casting	30.60	sq. ft.
Area of opening in car	12.37	sq. ft.
Mean areas of lining: Cylindrical portion	171.50	sq. ft.
Mean areas of lining: Conical portions (both)	171.90	sq. ft.
Mean areas of lining: Ends (both)	18.10	sq. ft.
Average thickness of lining beneath trunnion castings	15	inches
Average thickness of lining through conical portions	11	inches
Average thickness of lining through cylindrical portions	13	inches

Table 2

TEMPERATURE OF MOLTEN METAL IN HOT METAL CAR

	Degrees Cent.	Degrees Fahr.
Temperature of inside surface of car before filling	910	1670
Temperature of molten metal at dam (average)	1490	2714
Temperature of molten metal entering car (average)	1485	2705
Temperature of metal after 20 minutes	1437	2619
Temperature of metal after 1 hour	1422	2592
Temperature of metal after 2 hours	1410	2570
Temperature of metal after 3 hours	1400	2552
Temperature of metal after 4 hours	1391	2536
Temperature of metal after 5 hours	1383	2521
Temperature of metal after 6 hours	1375	2507
Temperature of metal after 7 hours	1368	2494
Temperature of metal after 8 hours	1362	2484
Temperature of metal after 9 hours	1356	2473
Temperature of metal after 10 hours	1350	2462
Temperature of metal after 11 hours	1344	2451

Table 3

COOLING RATE OF MOLTEN METAL

	Degrees per Hour Cent.	Degrees per Hour Fahr.
First hour	63	113
Second hour	12	22
Third hour	10	18
Fourth hour	9	16
Fifth hour	8	14
Sixth hour	8	14
Seventh hour	7	13
Eighth hour	6	11
Ninth hour	6	11
Tenth hour	6	11
Eleventh hour	6	11

Table 4

EXTERNAL SURFACE TEMPERATURES

Time	*A Portion* Degrees Cent. Average	Range	*G Portion* Degrees Cent. Average	Range
1 hour before filling	63	..-..	41	..-..
2 hours after filling	79	68-89	70	64-77
3 hours after filling	81	72-88	72	67-77
4 hours after filling	81	74-86	74	70-77
5 hours after filling	80	76-85	78	74-83
6 hours after filling	81	77-84	79	77-84
7 hours after filling	80	75-88	82	77-88
8 hours after filling	80	73-90	83	77-91
9 hours after filling	82	73-92	79	70-85
10 hours after filling	81	67-89	71	62-84

Time	*B Portion* Degrees Cent. Average	Range	*F Portion* Degrees Cent. Average	Range
1 hour before filling	96	...-...	101	...-...
2 hours after filling	156	147-170	163	154-186
3 hours after filling	162	156-173	168	161-189
4 hours after filling	167	160-177	173	165-192
5 hours after filling	168	151-181	178	168-196
6 hours after filling	173	164-184	181	172-200
7 hours after filling	178	171-184	182	171-199
8 hours after filling	181	175-188	184	170-197
9 hours after filling	182	174-193	182	158-190
10 hours after filling	180	170-194	175	155-188

Time	*C Portion* Degrees Cent. Average	Range	*E Portion* Degrees Cent. Average	Range
1 hour before filling	96	...-...	107	...-...
2 hours after filling	154	138-178	163	145-194
3 hours after filling	159	150-180	167	148-198
4 hours after filling	163	153-182	171	151-202
5 hours after filling	164	153-185	175	154-206
6 hours after filling	166	153-187	178	155-209
7 hours after filling	167	153-185	181	156-209
8 hours after filling	169	158-181	184	158-210
9 hours after filling	171	156-179	185	153-214
10 hours after filling	166	144-178	180	142-214

Time	*D Portion* Degrees Cent. Average	Range	*Trunnion Bearing* Degrees Cent. Average	Range
1 hour before filling	173	...-...	..	..-..
2 hours after filling	208	172-228	23	19-25
3 hours after filling	213	173-236	23	20-24
4 hours after filling	218	174-245	23	21-25
5 hours after filling	223	175-254	22	20-25
6 hours after filling	228	176-263	22	18-26
7 hours after filling	231	178-267	21	16-26
8 hours after filling	234	180-273	21	17-26
9 hours after filling	229	164-283	22	16-26
10 hours after filling	223	148-289	23	12-27

Time	Spout Casting Degrees Cent. Average	Range
7 hours after filling	175	...-...
8 hours after filling	150	...-...
9 hours after filling	174	147-200
10 hours after filling	140	122-158

(Continued on next page)

Table 4

(Continued)

Time	Atmospheric Temperature Degrees Cent.
1 hour before filling	-2
While filling	12
1 hour after filling	11
2 hours after filling	12
3 hours after filling	13
4 hours after filling	14
5 hours after filling	13
6 hours after filling	12
7 hours after filling	11
8 hours after filling	10
9 hours after filling	8
10 hours after filling	6

Table 5

DETERMINATION OF EMISSIVITY OF MOLTEN IRON IN RUNNER

Temperature of Metal in Runner by Thermocouple Degrees Cent.	Apparent Temperature by Optical Degrees Cent.	Difference Degrees Cent.	Calculated Emissivity
1455	1324	131	0.35
1477	1330	147	0.33
1479	1315	164	0.28
1479	1365	114	0.42
1479	1330	149	0.32
1483	1347	136	0.35
1512	1365	147	0.34
		Average	0.34

Table 4 gives the average surface temperatures and the maximum and minimum temperatures for each portion of the car during the test. The minimum temperatures occurred on the side exposed to the windows while the maximum temperatures occurred on the opposite side.

Table 5 gives some apparent temperatures of the metal in the runner, as observed by the optical pyrometer, and the apparent emissivity of the iron. The metal was carrying considerable slag making it very difficult to obtain satisfactory readings.

In order to measure the temperatures of the lining at various depths a 3/8-inch hole was drilled close to the G trunnion casting. Then by means of a star-drill, a hole was drilled into the lining and readings of the temperatures were obtained at various depths up to seven inches. The thickness of the lining was

approximately 11 inches, the thickness of the shell one inch and the temperature of the shell about 100 degrees Cent.

Table 6 gives the observed temperatures at various depths. The observations were made after the car had been filled for seven hours and were completed within an hour.

The temperature readings in Table 6 are probably low because it was necessary to cool the drill with water and as a result some water was carried into the hole with the drill which cooled off the lining at this point. About five minutes was permitted to elapse before making each observation, but this was not sufficient time for the temperature to return to equilibrium. Since these measurements involve some hazard and are subject to considerable uncertainty and since the results indicate that the values obtained are not representative of the temperatures in the lining it appears that measurements of this kind are of little value.

Table 6

Depth of hole from the inside of shell, inches	Temperature Degrees Cent.
0.00	100 (Approx.)
1.50	237
3.50	395
4.25	447
4.50	519
4.75	539
5.00	539
6.25	656
7.00	751
11.00	1365 (from temp. of metal)

The convection losses given in this report are based upon data[8] correlated by the Bureau of Standards and apply for natural convection from vertical surfaces. The fact that the surface of the car was not vertical would tend to make the convection losses lower than the calculated losses but this difference would probably be more than overbalanced by the wind blowing through the ladle room which would increase the convection losses.

Table 7 gives the heat losses by natural convection from vertical surfaces at various temperatures when the temperature of the surroundings is at 10 degrees Cent.

[8] Griffiths and Davis, Special Report No. 7, Food Investigation Board, Dept of Sci. and Ind. Res. Great Britain. Langmuir—Trans. Amer. Elect. Chem. Soc., 23, p. 314, 1913.

The radiation losses from the surface were computed by using the Stefan-Boltzmann radiation law.

$$J = KE\ (T_1^4 - T_0^4)$$

where J is the amount of energy radiated in gram-calories per square centimeter per second; K is a constant equal to 1.36×10^{12}, E is the total emissivity and assumed equal to 0.8 for an oxidized steel surface at 200 degrees Cent. T_1 is the absolute centigrade temperature of the radiating surfaces and T_0 is the absolute centigrade temperature of the surroundings.

The radiation losses from the opening were determined in the same manner with the exception that an emissivity of 1.0 was used since the slag covering on the iron and the deep opening approximate black body conditions. The temperature of this surface was approximately 500 degrees Cent.

Table 7

Surface Temperature, Degrees Cent.	Convection Loss, Calories per Square Centimeter per Second
22	0.0010
60	0.0063
80	0.0096
100	0.0133
120	0.0171
140	0.0211
160	0.0251
180	0.0292
200	0.0334
220	0.0378
240	0.0421
260	0.0465
280	0.0510

The amount of heat conducted through the lining was determined by the equation:

$$H = \frac{A}{L} C\ (t_2 - t_1)$$

where H is the amount of heat conducted through the lining in gram-calories per square centimeter per second; C is the conductivity of the fire brick lining and taken equal to 0.0024.* A is the mean area of the lining in square centimeters; L is the thickness of the lining in centimeters; t_2 is the inside temperature of the lining in degrees Cent. (taken equal to the temperature of

*Bureau of Mines Reports of Investigations, No. 2564, Jan., 1924.

the iron), and t_1 is the outside temperature of the lining in degrees Cent. (taken equal to the average temperature of the shell).

Table 8 gives the losses from the principal sections of the car ladle. The radiation and convection losses are tabulated as such while the conduction loss corresponds to the heat conducted through the lining for the corresponding section. After steady conditions have been attained the sum of the radiation and convection losses should be approximately equal to the heat conducted through the lining. Since both methods of obtaining the heat loss contain uncertainties of the same order of magnitude, the loss obtained by one method is no more reliable than that obtained by the other.

These tabulated losses are the average over the last two

Table 8

HEAT LOSSES FROM CAR

Portion	Radiation Loss, Kilocalories per Second	Convection Loss, Kilocalories per Second	Total Loss, Radiation Plus Convection	Conduction Through Lining
Trunnion castings and bearings A+G+ bearings	0.64	0.61	1.25	1.35
Conical portions B+F	7.18	5.39	12.37	16.12
Cylindrical portions C+D+E	7.90	5.57	13.47	13.46
Spout casting	0.84	0.69	1.53	....
Opening	5.48	....	5.48	5.48*
Total	22.04	12.26	34.30	36.41

Average value of heat loss 35.35 kilocalories per second.

*Taken equal to radiation loss.

hour periods that observations were made; that is, for the time period of from 8 to 10 hours after filling the ladle. From all indications steady conditions had been attained by this time.

The heat losses by radiation and convection agree with the conduction loss more closely than might be expected due to the uncertainty in the constants used in the calculations, and experimental errors in the measurements. The uncertain factors are the convection losses, the total emissivity of the surface of the shell and the conductivity of the fire brick. The uncertainty in these values is much greater than the difference in the heat losses calculated by the two methods.

A value for the specific heat of the molten iron can be calculated from the loss in heat from the car and from the rate of change of the temperature of the iron. It will be necessary, however, to assume values for the specific heat of the shell and of the lining and also assume that the temperature drops uniformly through the lining. The assumed and calculated values are given below:

Specific heat of steel shell (assumed)....0.12
Specific heat of lining (assumed).......0.26
Average drop in temperature of molten metal over the last two-hour period................6.0 degrees Cent. per hour
Average drop in shell temperature over the last two-hour period......................2.6 degrees Cent. per hour
Average drop in lining temperature over the last two-hour period.......................4.3 degrees Cent. per hour
Loss of heat from surface.........35.35 kilocalories per second
Heat loss from surface per hour..........127,300 kilocalories
Heat given up by lining per hour.......... 29,100 kilocalories
Heat given up by shell per hour.......... 6,700 kilocalories
Heat given up by molten iron per hour.... 91,500 kilocalories
Specific heat of molten iron = 0.23

This value of specific heat of the iron may be in error due to the fact that the weight and rate of cooling of the slag was not known and that some of the iron was freezing in with the slag.

The rate of heat loss given in this report may also be used to estimate the rate of heat loss from larger or smaller cars of similar types, since if the thickness of lining is the same, surface temperatures should be about those observed in these tests, and under these conditions the heat loss would be proportional to the area of the surface.

Summary

Temperature measurements on a 75 ton hot metal car with external surface of 550 square feet (exclusive of opening) showed the heat loss to be 35.35 kilocalories per second. This value is the mean of the conduction through the lining (36.41 kilocalories per second) and the sum of total radiation and convection losses (34.30 kilocalories per second).

In a filled car of the type and size described the cooling rate of the metal after the first few hours was found to be about 6 degrees Cent. per hour, which indicates that metal tapped from a blast furnace at approximately 1500 degrees Cent. can be held for 40 hours before freezing.

From the data obtained the apparent specific heat of molten pig iron at approximately 1350 degrees Cent. was calculated to be 0.23.

Cost Finding Practice for Steel Foundries

The cost finding practice for steel foundries which is described in this paper and prepared by the Steel Founders' Society of America, is recommended for use in all steel foundries by the Cost Committee of the American Foundrymen's Association as a means of promoting the needed use of uniform cost accounting principles in the casting industry.

A. E. HAGEBOECK, *Chairman*,
A. F. A. Committee on Foundry Costs.

Introduction

The subject of cost accounting is frequently considered by some to be beyond their power to comprehend, although it involves nothing mysterious and it can be readily understood by those not familiar with accounting theory and procedure. Cost accounting is really nothing more than the adaptation of common sense in a systematized manner for the purpose of providing facts and figures for use as guides in efficient management.

The purpose here is to outline a standard cost finding system for steel foundries, in a manner that makes it easily understood by the practical foundryman. The language of the cost accountant has been converted so far as possible into every-day language, thereby eliminating terms and expressions which sometimes cause difficulty in understanding the principles of cost accounting. Every foundry executive should possess knowledge of these principles for application to his business.

Due to the enormous capacity of the foundry industry, a very keen competitive condition exists. Hence, the concerns that are to prosper will be those who have an intimate knowledge of the cost of doing business, and who use cost finding methods accepted as uniform in their industry. Uniformity in cost finding methods among members of an industry such as the steel casting industry is without any question very beneficial in promoting intelligent trade practices.

Uses of an Effective Cost System

The uses of an effective system of cost accounting in a foundry may be summarized thus:

1. To ascertain the cost of making castings.
2. To measure the efficiency of labor.
3. To ascertain the consumption of materials and supplies.
4. To serve as a guide for correcting faulty operating methods.
5. To provide the stimulus of chronological comparative records.
6. To furnish data for intelligent merchandising.

A foundry cost system that properly serves the above purposes must be practicable in operation. The data required by executives must be so arranged that they may be transmitted to operating and sales executives in a systematic manner, permitting quick and accurate analysis.

From the above, it is manifest that cost accounting has three general functions to perform. It must provide data for the preparation of financial statements; it must serve the management in controlling operations; and it must be a means for preventing a serious loss in meeting competition.

Uniform Cost Finding Methods

Uniform methods of cost finding in an industry are without question very beneficial in promoting stability, business economy, efficient management, and lower costs. Uniform cost finding implies the use of the same principles and should not be construed as the use of standardized cost figures for an industry.

There are two fundamental requirements for uniform cost

finding: viz., the use of a standard classification of accounts and division of the business into departments, and the use of a uniform method of applying indirect and overhead expense to individual castings. The first requirement insures the charging of all the elements of cost to the proper accounts or departments. The second requirement is an aid in the elimination of great differences in costs among various foundries, which are caused chiefly by the use of different methods of applying indirect and overhead expense to individual castings.

A uniform method of cost finding in an industry is especially advantageous for establishing marketing policies. Vast differences in the costs of making specific castings at various foundries are usually due more to the use of different methods of cost finding than to methods of production or other economic conditions. The only true and logical differences in costs that should occur are those caused by the local conditions at certain foundries which enable the production of castings at different costs from those at other foundries. Wide variations in costs due to the use of different cost finding methods are apt to be detrimental to the entire industry, and therefore, they should be minimized by the use of a more uniform cost accounting practice. There will always be differences in costs of making castings at various foundries, but these differences should be caused only by certain local conditions, such as location of plant, management, shop practice, purchasing, etc.

Advantages of a Uniform Cost System

Among the many advantages offered by uniform cost accounting in an industry, the following are cited by the Department of Manufacture of the Chamber of Commerce of the United States in its pamphlet entitled "Uniform Cost Accounting in Trade Associations":

"1. Provides the 'one best way' known to the industry to figure costs (although cost accounting is a progressive science and provision should be made for keeping the uniform methods up-to-date), thereby eliminating expensive experimentation by the members of the industry individually and independently.

"2. Results in a better informed competition within the industry.

"3. Inspires confidence in the public that selling prices are established by producers who have full knowledge of the costs of the articles offered for sale.

"4. Tends to make the manufacturer, who otherwise would fail to see the advantages of good cost accounting, convinced of the desirability of adopting the methods which his competitors are successfully using.

"5. Reveals lines of individual products which have been marketed on an unprofitable basis.

"6. Provides in addition to the above specific reasons, all of the valuable features of good cost accounting generally, among which are the following:

(a) Shows the danger line below which goods cannot be sold at a profit; thus serving as an insurer of profits.

(b) Acts as a guide to the value, efficiency, and waste of workers, machines, methods, operations, and entire plants.

(c) Provides a reliable guide and basis for estimating the cost of prospective business.

(d) Furnishes current reports for comparing major cost items with standards which are predetermined, and thereby measures and increases operating efficiency."

Cost Divisions of the Foundry

The *Melting Department* includes the cost of metals and the conversion cost. It controls all labor, including melting, handling, and preparation of scrap, furnace maintenance and repairs, connected with the furnaces and with the ladles used for receiving the metal from the furnace spout; and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the melting stock and fuel at the storage point and ends at the point where the metal is poured into or from the ladle used for receiving the metal at the furnace spout. All items of cost incurred within these limits are charged to the Melting Department.

The *Molding Department* controls all the labor of molding,

the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the materials entering into molding sand mixtures at their point of storage and with the pouring of the metal into or from the ladle used for receiving the metal at the furnace spout. Its province ends with the delivery of the castings to the Cleaning Department. All items of cost incurred within these limits are charged to the Molding Department. It is important that the direct molding labor be segregated in a separate account in the Molding Department.

The *Coremaking Department* controls all the labor of coremaking, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the materials entering into core sand mixtures at their point of storage, and ends with the delivery of the finished cores to the Molding Department. All items of cost incurred within these limits are charged to the Core Department. It is important that the direct coremaking labor be segregated in a separate account in the Core Department.

The *Cleaning and Finishing Department* controls all the labor of cleaning and finishing castings, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the receipt of the castings from the molding department or pouring floor, and ends with the delivery of them to the shipping department. All items of cost incurred within these limits are charged to the Cleaning Department with the exception of annealing or heat-treating cost, which may be considered separately. It is important that the direct cleaning labor be segregated separately from the other accounts in the Cleaning Department.

The *Heat Treating Department* controls all the labor in connection with the annealing, normalizing, and other methods of heat-treating castings, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. All items of cost incurred in the heat-treatment of castings are charged to the Heat Treating Department.

The *General Expense* includes all the items of cost and expense not enumerated in the above departments and not chargeable specifically to those departments. Such expenses are: power, light and heat; general repairs not chargeable direct to the above departments; yard department; shipping; engineering; storekeeping; purchasing; production or order department; accounting department; inspection; safety and welfare; insurance; taxes; depreciation; pattern department expense not charged direct to specific patterns or orders; loss on defective castings after shipment; general office expense; advertising; selling; loss on bad debts; management salaries; officers' salaries; traveling expenses; incoming freight not charged to material accounts or to departments in which materials are used; research; reserve for inventory adjustments; other operating reserves of a general nature; etc.

Classification of Accounts

The following standard classification of cost accounts, based on the cost divisions of the foundry outlined above, is recommended for steel foundries:

Melted Metal Department:

Metals: (See Note 1, page 31)

Pig iron	Ferro Silicon
Purchased scrap	Iron ore
Own scrap	Alloys
Ferro manganese	

Fuel: (See Note 1)

Fuel oil for furnaces and ladles	Gas for furnaces and ladles

Power:

For electric melting furnaces

Supplies:

Silica sand	Lumber
Coal	Nails
Ladle brick	Sleeves
Ladle loam	Stoppers
Ganister	Nozzles
Aluminum	Furnace tools
Waste	Oxygen

Lubricants	Lime
Incandescent lamps	Chemical laboratory supplies and apparatus
Bar iron and steel	Electrodes for electric furnaces. (It is desirable to have a separate account for this item.)

Labor:

Melters	Chemists
Helpers	Ladlemen
Chargers	Melting department clerks
Stockers	Melting foremen
Drop operators	Cranemen

Furnace Repairs—Labor: (See Note 2)

Brick masons	Steel workers
Masons' helpers	Laborers

Furnace Repairs—Material: (See Note 2)

Brick	Castings
Sand	Supplies
Structural steel	

Other Repairs—Labor:

Labor repairing all other equipment in Melting Department except furnaces.

Other Repairs—Material:

Material and other charges for repairs to all other equipment in Melting Department except furnaces.

Note 1. The cost of freight on materials used in this department, and the cost of unloading these materials are to be charged to the materials, or are to be charged to the Melting Department in a separate account. The natural waste that occurs in the storage and handling of the metals and the discrepancies that occur in inventories, should be covered in the monthly cost of metals. This is done by adding a certain percentage to the actual amount of each of the metals used, thereby avoiding the necessity for making large stock pile adjustments adversely affecting the business. The reserve for inventory adjustments explained

on page 45 should not include an amount to cover reserve for metals, as the latter is charged direct to the cost of metals in the manner just outlined.

Note 2. A reserve fund for furnace repairs should preferably be created by charging to costs each month an amount based upon a predetermined rate per ton of metals charged into the furnaces. When actual repairs are made, they are charged to the reserve fund. The labor and material accounts for furnace repairs may be combined at the option of the foundry.

Note 3. The costs of physical tests are to be charged to the Melting Department when the making of these tests is under the direction of the chemical laboratory, or to the general overhead expense when under the direction of some other department.

Molding Department:

Molding Direct Labor

Molders	Finishers
Apprentices	Dry-floor molders
Helpers	Dry-floor helpers
Rammers	

Molding Indirect Expense

Indirect Labor:

Cranemen	Runner cup makers
Chainmen	Core carriers
Labor pouring and following heats	Pattern carriers
	Tool-room labor
Shakeout labor	Gagger-men
Flask fitters	Sand-mill labor
Sand reclaiming labor	Mold checkers
Mold-oven tenders	Dry-floor laborers

Other labor not charged to direct labor.

Supervision:

Foremen and assistant foremen in molding department
Molding department clerks.

Flasks: (See Note 4 page 33)

Labor and material used for making new wood and metal flasks and repairing them, including bottom

boards, plates and cross-bars.

Other Repairs:

Labor and materials used for making repairs to all equipment in molding department except flasks referred to in the previous account.

Molding Sand:

Cost of molding sand including freight and unloading.

Fuel:

Cost of fuel including freight and unloading for mold-drying ovens.

Supplies:

- Chaplets
- Nails
- Bar iron and steel
- Gaggers
- Silica flour
- Molasses and glutrin
- Fire clay
- Flour
- Dextrine
- Other compounds used in molding sand mixtures
- Chains
- Belt dressing
- Lubricants
- Waste
- Air hose and fittings
- Incandescent lamps
- Bolts
- Clamps
- Shovels
- Riddles
- Brushes
- Lumber
- Rammers and rammer butts
- Tools

Note 4. Preferably a reserve fund should be created for flasks by charging to costs monthly an amount based upon a predetermined rate per net ton of castings produced. The actual expenditures for new flasks and repairs should be charged to this reserve fund.

Core Department:

Core Direct Labor

Coremakers, apprentices, and any other labor in the Core Department that can be specifically followed and charged direct to a job.

Core Indirect Expense

Indirect Labor:

Core oven tenders	Sand-handlers
Plate handlers	Core carriers
Cranemen	Core box carriers
Chainmen	Other labor not charged to direct labor
Sand-mill labor	

Supervision:

Foremen and assistant foremen in Core Department

Core Department clerks.

Repairs:

Labor and material used for making repairs to all equipment in Core Department.

Core Sand:

Cost of core sand including freight and unloading.

Fuel:

Cost of fuel including freight and unloaidng for core ovens.

Supplies:

Nails	Brushes
Bar iron and steel	Air hose and fittings
Plates	Lubricants
Silica flour	Incandescent lamps
Molasses and glutrin	Lumber
Fire clay	Shovels
Flour	Riddles
Core compounds	Tools
Bolts	Rammers and rammer butts
Chains	

Cleaning Department:

Cleaning Direct Labor

Floggers	Saw operators
Chippers	Cutting torch operators
Grinders	Press operators (straightening castings)

Machine work labor necessary to prepare castings for shipment "in the rough."

Cleaning Indirect Expense

Indirect Labor:

Cranemen	Truckers
Chainmen	Welding labor
Tool-room men	Sand-blast labor
Clean-up labor	Other labor not charged to direct labor.
Tumbling barrel labor	

The above distribution of direct and indirect labor in the Cleaning Department is suggested for use by steel foundries. Some foundries may find it desirable to change some item or items to direct or indirect labor, but all the above operations should be charged to the Cleaning Department consistently.

Supervision:

Foremen and assistant foremen in Cleaning Department.
Cleaning Department clerks.

Repairs:

Labor and material used for making repairs to all equipment in Cleaning Department.

Supplies:

Emery wheels	Welding carbons
Chisels and cutters	Saw-teeth and blades
Oxygen	Lubricants
Acetylene and carbide	Cutters for machine tools
Cutting and welding torches and tips	Chains
Air hose and fittings	Incandescent lamps
Blasting abrasives	Brushes
Blasting hose and nozzles	Hammers, sledges, and handles
Pneumatic hammers	Tools
Welding wire	

Heat Treating or Annealing:

Labor:

Foremen, oven tenders, loading and unloading furnaces and other labor engaged in annealing castings.

Fuel:

Cost of fuel including freight and unloading used in annealing furnaces.

Supplies:

Cost of all supplies used in annealing department.

Repairs:

Cost of labor and material used for making repairs to annealing equipment.

General Overhead:

This includes all expenses of the business not enumerated in the foregoing accounts.

Steam, Power and Light:

Labor, material, supplies, and repairs used in operating power plant

Purchased power, except power for electric furnaces

Water

Yard:

Labor, material, supplies, and repairs used in Yard Department. Also drayage, auto trucks, locomotive cranes, car demurrage, track maintenance, and waste removal.

Inspection:

Inspectors examining castings.

Pattern Department:

Labor:—Foremen, assistant foremen, pattern makers, and other labor making, altering, and repairing patterns that is not charged directly to the customer, nor to Special Charges.

Material and Other Charges:—Material, supplies, repairs to pattern shop equipment, and other pattern expense for making, altering, and repairing patterns that is not charged directly to the customer, nor to Special Charges.

(Refer to section on Special Charges.)

Safety, Casualty, Welfare, and Pensions.

Shipping:

Labor:—Shipping clerks and assistants, cranemen, chainmen, and other labor in Shipping Department.

Material and Other Charges:—Material, supplies, and other charges used in preparing castings for shipment.

General Repairs:

Labor:—Repair department foremen and assistants, machinists, electricians, pipe fitters, and other labor repairing buildings, machines, and equipment of a general nature not applicable to the repair accounts in the departments mentioned previously.

Material, supplies, and spare parts used in repairing buildings, machines, and equipment of a general nature not applicable to the repair accounts previously specified.

Pattern Storage.

Insurance.

Taxes:

To include all taxes except Federal and State Income Taxes.

Loss on Defective Castings after Shipment: (See Note 5, page 39)

Difference between the sales value and the scrap value of castings shipped to customers and rejected, plus the freight, etc.

Charges for work done by customers to make the castings meet their requirements.

Cost of labor at foundry in making castings rejected and returned by customers suitable for acceptance by such customers.

Depreciation: (See Note 6, page 39)

For depreciation of entire plant and its equipment.

Clerks' Salaries:

Includes salaries of all clerks and stenographers, except department clerks in the metal, molding, core, and cleaning departments.

Accounting Department:

Salaries, wages, material, supplies, and other charges used in operating the accounting department.

Management Salaries:

Works manager, assistant works manager, general superintendent, etc.

Engineering Department:

Salaries, wages, material, supplies, and other charges used in operating the engineering department.

Purchasing Department:

Salaries, wages, supplies, etc., used in operating the purchasing department.

Miscellaneous Operating Expense:

Labor:—Wages of employes engaged in work of a general nature and not otherwise specified, such as watchmen, janitors, police, experimental, and development.

Material:—Material and supplies of a general nature and not otherwise specified, such as telephone, telegraph, stationery, ice, laundry, traveling expense of operating men, etc.

Inventory Adjustment:

Reserve fund for inventory adjustment to be created by charging to costs monthly an amount based upon a predetermined rate per net ton of good castings produced.

Administrative Expense:

Salaries and expenses of executives	Postage
Head office rental	Telegrams
Legal expense	Traveling expenses
Subscriptions	Reserve for doubtful accounts (See Note 7, page 39)
Dues	Auditing expense
Directors' fees	

Selling Expense:

Salaries and commissions of salesmen	Advertising
	Branch office expense

Traveling expense of salesmen
Clerks, stenographers, and others in sales department
Postage
Telegrams
Stationery and supplies for sales department.

Note 5. Preferably a reserve fund for loss on defective castings after shipment should be created by charging to costs monthly an amount based upon a predetermined rate per net ton of good castings, or an amount based upon a predetermined percentage of total sales to customers.

Note 6. Depreciation should be provided for regularly each month upon some definite and suitable basis, and charged to monthly costs.

Note 7. A reserve fund for doubtful accounts or bad debts should be created by charging to costs monthly an amount based upon a predetermined percentage of total sales, or an amount based upon a predetermined rate per net ton of good castings.

Special Charges

Pattern Expense:

Labor:—Wages of pattern makers and other labor making, altering, and repairing pattern equipment that is charged direct to a specific pattern.

Material and Other Charges:—Material and supplies used for making, altering, and repairing pattern equipment that is charged direct to a specific pattern. Also the cost of patterns, templates, and gauges purchased from outside concerns.

Special Rigging:

Labor:—Wages of labor engaged in making special equipment or rigging that is charged direct to a specific pattern, or to castings made from a specific pattern.

Material and Other Charges:—Material and supplies used in making special equipment or rigging that is charged to a specific pattern, or to castings made from a specific pattern.

Special Machining:

Labor, material, and supplies in connection with special

machine work that is charged direct to a specific pattern, or to castings made from a specific pattern.

Product of Metals Charged into Furnace

Good Castings:

The weight of the good castings produced is obtained by adding to the weight of the castings shipped during the month the weight of the castings on hand at the close of the month, and deducting therefrom the weight of the castings on hand at the beginning of the month. If this method is followed, inventories should be obtained by weight or count, and should not be blanket estimated.

Defective Castings:

The weight of the defective castings is obtained from the defective casting reports and it represents the castings scrapped in the foundry. It should not include defective castings returned to the foundry by customers, as such losses are included separately in General Overhead Expense. This item does not include the heads and gates on defective castings.

Slagged Castings:

The weight of the castings slagged at the end of heats, is also obtained from the defective casting reports.

Heads and Gates:

The weight of the heads and gates is obtained by actual weights wherever practicable. When it is not practicable to weigh heads and gates, their weight is obtained by deducting from the total furnace charge the sum of the weights of the good castings, the defective castings, the slagged castings, the metal losses, and the melting and foundry loss. This item includes the heads and gates on defective castings.

Metal Losses:

This item includes steel poured from the furnace that is later recovered as scrap in the form of lost heats, spills, skulls, runner cup scrap, fins, steel poured into

pigs, and other scrap that is recovered. Experience has demonstrated that this metal loss is usually 3 per cent to 5 per cent of the total metal charged into the furnaces.

Total Scrap:

This item is the sum of the weights of the defective castings, slagged castings, heads and gates, and metal losses. The weight of the total scrap produced during the month is a known quantity as it is obtained by adding to the weight of "Own Scrap" charged into the furnace during the month, the weight of "Own Scrap" on hand at the end of the month, and deducting from this sum the weight of "Own Scrap" on hand at the beginning of the month. "Own Scrap" means steel poured from the furnace that is later recovered as scrap from the manufacture of castings, that is, it is all scrap which is returned to the furnaces for remelting.

Melting and Foundry Loss:

This item represents all metal that is lost and cannot be recovered, such as oxidation loss during melting, oxidation loss during annealing, fins and spills lost in heap sand, metal removed and lost as dust in grinding castings, oxidation loss during the removal of heads and gates by gas cutting, and other metal unaccounted for. This melting and foundry loss can be determined periodically from calculations involving inventories of "own scrap," the weight of the castings scrapped during the period, the weight of the good castings produced during the period, and the total amount of all metals charged into the furnaces during the period. It is usually from 7 per cent to 10 per cent of the metal charged for foundries operating open hearth furnaces or electric furnaces, and from 18 per cent to 22 per cent for foundries operating converters.

Total Charge:

The total charge is the total weight of the metals charged

into the furnaces during the month. This is obtained from the heat reports and it represents actual weights of metals used.

Accounting for Materials, Supplies and Other Charges

Data for the various items in the Standard Classification of Cost Accounts pertaining to the cost of materials, supplies, and other charges, are obtained from heat reports, monthly inventories, stores' requisitions, voucher records, and reserve accounts in the cost ledger. It is important that these charges be correctly classified and applied to the proper cost accounts.

Accounting for Labor

Labor is of the greatest importance to the foundrymen because it is most potent in contributing toward the success or failure in making castings. It is one of the items most susceptible to manipulation and economy.

The method of collecting labor data for the cost accounting records is very important, unless it is performed with accuracy and ease the results are unreliable and misleading. Since the costs of individual castings are dependent largely on correct labor costs, it is evident that incorrect labor data may lead to disastrous cost finding.

The labor data for the various accounts given in the Standard Classification of Cost Accounts, are obtained from the records used for distributing the time or service records for all employes to the different accounts in each department, that is, the classification of labor according to its nature. Data for employes receiving salaries are obtained from the salary roll.

Depreciation

Depreciation of the plant and equipment must be charged into current costs of production as it is an item of expense. The need of charging depreciation to current costs arises from the fact that working assets gradually give out or become obsolete, or in other words, they are used up in production, and the cost of this usage or consumption of capital is part of the cost of the product being manufactured.

The test for depreciation is how long the property will func-

tion, how many units it will produce before it is scrapped or becomes obsolete, and what will be its cost of replacement. When this question is answered, then the amount of depreciation—which is the actual cost of the property less any salvage—to be charged to current costs can be determined. This charge to costs for depreciation cannot be abandoned simply because profits are non-existent, for depreciation accrues whether or not there is a dollar of profit.

It is preferable that depreciation bé accumulated in a depreciation reserve account, charging costs of production each month and crediting the depreciation reserve in the general ledger. This reserve is directly affected when renewals are made and when the property is exchanged, sold, replaced, or abandoned.

Capital and Revenue Expenditures

In cost accounting practice it is necessary that intelligent decisions be made as to the ultimate disposition of expenditures, that is, whether they are chargeable to the asset accounts or to the current cost accounts. Those charged to the asset accounts are capital expenditures, and those charged to the cost accounts are revenue expenditures.

Capital expenditures apply to such expenses as, in the aggregate, represent the cost of the increased earning capacity of the plant as a whole or of particular parts thereof, which has been secured over the earning capacity known to exist before the said expenses were incurred.

Revenue expenditures, which are charged to current costs of production, apply to such expenses that must be incurred in order to obtain advantage of the earning capacity of the plant or of particular parts thereof, in order that such capacity may be maintained at the required standard.

Operating Reserves

Operating reserves measure the amount of the cost of operations which, while not necessarily expended at the present time, will positively be incurred according to past experience. They represent costs of production incurred and unpaid, and the only connection they have with surplus is that, if unnecessarily high,

they will be sent in part to the credit of the surplus account in order to remove any prejudice that it has suffered through over-conservatism in the charges to current manufacturing costs.

The following reserve accounts are recommended for use in the modern steel foundry cost accounting system:

Reserve for Depreciation. A definite sum is charged to manufacturing costs, under General Overhead Expense, each month, and the same amount is credited to the depreciation reserve account in the ledger.

Reserve for Furnace Rebuilding and Repairs. A definite amount per net ton of metal charged into the furnace is charged to Metal Department costs monthly, and this same amount is credited to the reserve account in the ledger. As expenditures are made for furnace rebuilding and repairs they are debited to the reserve account in the ledger. The debits to this ledger account and the tonnage charged during a period, form the bases for establishing the rate per net ton of metal charged to be absorbed in costs monthly.

Reserve for Flasks. A definite amount per net ton of castings produced is charged to Molding Department costs each month, and the same amount is credited to the reserve account in the ledger. As expenditures are made for new flasks and repairs, they are debited to the reserve account in the ledger.

Reserve for Doubtful Accounts. A definite amount per net ton of good castings or a definite percentage of total casting sales, is charged to costs each month under General Overhead Expense, and the same amount is credited to the reserve account in the ledger. As bad debts occur they are debited to the reserve account in the ledger.

Reserve for Loss on Defective Castings After Shipment. This covers losses from returned castings and losses from work done on castings, the cost of which is charged back to the foundry. A definite amount per net ton of good castings or a definite percentage of total casting sales, is charged to costs each month under General Overhead

Expense, and the same amount is credited to the reserve account in the ledger. As losses on defective castings after shipment from the foundry occur they are debited to the reserve account in the ledger.

Reserve for Inventory Adjustments. A definite amount per net ton of good castings is charged to costs each month under General Overhead Expense, to provide for adjustments in inventories that occur each year. The same amount is credited to the reserve account in the ledger. As adjustments are made they are debited to this reserve account. The reserve for adjustment of inventories of metals is charged direct to the cost of metals as explained in Note 1 on Page 31.

In addition to the above which represents the major items to be dealt with as reserves, there are others such as the following which may be taken care of as reserves by charging a fixed amount to costs each month under General Overhead Expense: Subscriptions and Dues, Donations, Legal and Auditing Expense, Property Taxes, Insurance, Research, etc.

Surplus Reserves

Surplus reserves, or simply surplus, are in effect a group of accounts which show the value of the equity belonging to stockholders over and above the par value of the outstanding shares of stock. They arise from net profits, and they are needed for such purposes as the following: Purchase and installation of new equipment to keep the plant up to date; General plant improvements; Federal Taxes; Business depressions; Regular payment of dividends during periods of good and bad business; Interest on notes and bonds; Sinking funds for retirement of notes, bonds, and stocks; Plant extensions; Contingencies, etc.

Proper cost accounting methods and uniform principles of establishing overhead or burden rates and their application in determining the costs of individual castings, are important means for enabling a foundry to set up and maintain surplus reserves which are necessary for the efficient conduct of a business and which must be established from profits.

Cost of Sales

The cost of sales must be determined from the cost accounting system and it is necessary for determining the profit or loss of the business. It represents the cost of castings shipped or invoiced to customers during the month, and may be obtained in the manner outlined below. To be conservative, it is recommended that the normal cost per ton used for pricing the inventory be reduced by an amount estimated as being the cost of cleaning the castings represented by the inventory.

1. The castings on hand at the beginning of the month, or the book inventory, are priced or can be priced by using an average total cost per pound or per ton for an average period of business. This will prevent fluctuations from month to month.

2. The castings produced during the month are priced at the total cost per pound or per ton for that month.

3. The castings on hand at the end of the month, or the shop inventory, are priced in the same manner as the pricing of the castings on hand at the beginning of the month.

4. The cost of sales for the month is the value of the book inventory (castings on hand at the beginning of the month) plus the value of the castings produced during the month, less the value of the shop inventory (castings on hand at the end of the month). This is the total cost of sales.

The net profit or loss is obtained by using the total cost of sales and the total net sales for the period.

Average or Normal Costs

Average or normal costs mean those representing average conditions of business, and they should always be used for establishing the overhead or burden rates necessary for determining actual and estimated costs of individual castings. This is true whether or not the average costs are higher or lower than the actual prevailing costs of carrying on the business during the various fluctuations in the rate of operation of the foundry caused by changing conditions of general business.

The expense which is logically chargeable to a casting is that

required for its manufacture when the plant is operated under average conditions, because the actual effort and use of the foundry's facilities required for making a casting are no less when the plant is operating at maximum capacity than when it is operating at a reduced rate. The total cost for the entire foundry per ton of castings produced is lower than the average cost during abnormal business conditions, and is higher than the average cost during subnormal business conditions. However, this does not mean that the cost of making an individual casting varies in the same manner as the actual total cost for the entire output, that is, it is not affected by general business conditions in the same manner as the latter. Therefore, the overhead or burden rates for use in obtaining costs of individual castings must be computed from a summary of costs representing average business conditions, meaning good, fair, and bad conditions, or, in other words, high, medium, and low rates of operation of the foundry. This summary of costs to be used might be an average of the costs for three years constituting a good year, a fair year, and a poor year, with respect to general business and foundry operations. It is very essential that this principle of using average costs covering average business conditions be used in practice, particularly for determining the costs upon which selling prices are based.

Monthly Summary of Cost of Production

A summary of the cost of production should be prepared each month. This summary should be compiled and arranged in accordance with the standard classification of accounts on page 30, although it is not necessary that each account be listed in the summary. The accounts may be condensed in a manner similar to that illustrated on the sample Monthly Summary of Cost of Production of Good Castings shown on the pages following. Many foundries supplement the Monthly Summary of Cost of Production of Good Castings with additional records giving in greater detail the items of cost used for compiling the summary, or they

Monthly Summary of Cost of

		Net Tons Charged	Price Per Net Ton	Cost Per Net Ton Charged	Total Amount	Cost per Net Ton Good Castings
	MELTED METAL					
	Pig Iron	120	25.00	2.50	3,000.00	4.55
	Purchased Scrap	647	18.00	9.71	11,646.00	17.64
	Own Scrap	410	13.00	4.44	5,330.00	8.08
	Ferromanganese	12	98.00	.98	1,176.00	1.78
	Ferrosilicon	6	78.00	.39	468.00	.71
	Iron Ore	5	4.50	.02	22.50	.04
	Special Alloys					
1	Total Metals	1200		18.04	21,642.50	32.80
	Labor			4.20	5,040.00	7.64
	Fuel			3.60	4,320.00	6.54
	Power KWH @ per KWH					
	Electrodes lbs.					
	Supplies			1.00	1,200.00	1.82
	Furnace Repairs			.90	1,080.00	1.64
	Other Repairs			.40	480.00	.72
2	Total Metals and Conversion			28.14	33,762.50	51.16
3	Less Scrap Recovered 420 Tons @ 13.00 per Net Ton				5,460.00	8.27
	Total Melted Metal				28,302.50	42.89
	DIRECT LABOR					
4	Molding				11,880.00	18.00
5	Core				3,300.00	5.00
6	Cleaning and Finishing				6,600.00	10.00
7	Total Direct Labor				21,780.00	33.00
	INDIRECT EXPENSE					
	MOLDING					
	Indirect Labor				6,600.00	10.00
8	Sand Mill Labor				660.00	1.00
9	Pouring Labor (Shank Ladles)					
10	Sand				1,188.00	1.80
11	Sand Mixture Ingredients				396.00	.60
	Fuel				264.00	.40
	Supplies				924.00	1.40
	Flasks				330.00	.50
	Repairs				1,254.00	1.90
	Supervision				1,584.00	2.40
12	Total Molding Indirect				13,200.00	20.00
	CORE					
	Indirect Labor				1,320.00	2.00
	Sand				462.00	.70
	Fuel				594.00	.90
	Supplies				990.00	1.50
	Repairs				495.00	.75
	Supervision				528.00	.80
13	Total Core Indirect				4,389.00	6.65
	CLEANING AND FINISHING					
	Indirect Labor				2,244.00	3.40
	Supplies				4,620.00	7.00
	Repairs				825.00	1.25
	Supervision				660.00	1.00
14	Total Cleaning and Finishing Indirect				8,349.00	12.65
	ANNEALING					
	Labor				726.00	1.10
	Fuel and Supplies				1,320.00	2.00
	Repairs				99.00	.15
15	Total Annealing				2,145.00	3.25
				Forward	78,165.50	118.44

Production of Good Castings

No.		Total Amount	Cost per Net Ton Good Castings
	Brought Forward	78,165.50	118.44
	GENERAL OVERHEAD EXPENSE		
16	Steam, Power, and Light	3,300.00	5.00
17	Yard	1,320.00	2.00
18	Inspection	990.00	1.50
19	Pattern Department	2,640.00	4.00
20	Safety, Casualty, Welfare, and Pensions	660.00	1.00
21	Shipping	1,980.00	3.00
22	General Repairs	3,300.00	5.00
23	Pattern Storage	330.00	.50
24	Loss on Defective (Back Charges, Returned Castings)	3,564.00	5.40
25	Miscellaneous Operating Expense	3,168.00	4.80
26	Insurance	1,980.00	3.00
27	Taxes	660.00	1.00
28	Depreciation	3,960.00	6.00
29	Clerks' Salaries	1,980.00	3.00
30	Accounting Department	990.00	1.50
31	Management Salaries	3,300.00	5.00
32	Engineering Department	990.00	1.50
33	Purchasing Department	825.00	1.25
34	Inventory Adjustment	330.00	.50
35	Administrative Expense	4,620.00	7.00
36	Selling Expense	4,455.00	6.75
37	Total General Overhead Expense	45,342.00	68.70
	Total	123,507.50	187.14
	SPECIAL CHARGES		
	Patterns and Gauges	990.00	1.50
	Special Rigging	132.00	.20
	Special Machining		
	Total Special Charges	1,122.00	1.70
	Total Cost	124,629.50	188.84

PRODUCT OF METALS CHARGED INTO FURNACES

No.		Net Tons	Percent of Total Charge
	Good Castings (yield)	660	55.00
	Scrap:		
	Defective Castings	44.4	3.70
38	Slagged Castings	3.6	0.30
	Heads and Gates	336	28.00
39	Metal Losses	36	3.00
	Total Scrap	420	35.00
40	Melting and Fdry. Loss	120	10.00
	Total Charge	1200	100.00

GOOD CASTINGS

	Net Tons
On Hand First of Month	100
Produced During Month	660
Total	760
Shipped During Month	600
On Hand Last of Month	160

OVERHEAD RATES FOR COST OF INDIVIDUAL CASTINGS

Molding Overhead	100×(Item 12 minus Sum of Items 8, 9, 10 and 11) divided by Item 4=92% of Molding Direct Labor.
	Sum of Items 8, 9, 10, and 11=$3.40 per Net Ton of Good Castings.
Core Overhead=(Item 13 divided by Item 5)×100=133% of Core Direct Labor.	
Cleaning and Finishing Overhead=(Item 14 divided by Item 6)×100=126.5% of Cleaning and Finishing Direct Labor.	
Annealing=Item 15=$3.25 per Net Ton of Good Castings.	
General Overhead	(Sum of Items 26 to 36 incl. divided by Item 7)×100=110.6% of Total Direct Labor.
	Sum of Items 16 to 25 incl.=$32.20 per Net Ton of Good Castings.
	Minimum=Item 37 divided by Maximum Production=45,342.00÷950=$47.73 per Net Ton.

NOTE:—All figures given in this cost summary are assumed, and they are used only for illustrating the principles advocated.

expand the Monthly Summary of Cost of Production to have it include more items than are shown on the sample illustrated here. Additional columns may also be added to it to provide for the inclusion of data for comparison purposes such as the costs per ton for the previous month, standard costs, best performance, etc.

The Monthly Summary of Cost of Production of Good Castings given on the pages following is inserted merely to illustrate the application of the cost finding principles advocated. All the figures on it are assumed, and each foundry must use its own cost data by following the procedure illustrated by the use of the assumed data.

Cost of Steel and Overhead Rates for Individual Castings

(a) *Cost of Steel*

The cost of steel per net ton of good castings is not the same for every casting, but it varies with the yield of good castings in percentage of metal charged into the furnace. Therefore, it is necessary to determine the yield for the casting whose cost is to be determined. This is a very important point.

The yield is the percentage of total metal charged into the furnace that results in good castings. To obtain the yield for a specific casting, the following data must be known: shipping weight of the casting, the weight of the heads and gates used on the casting, and the number or weight of the defective castings, including the heads and gates on them. The yield for the casting can then be calculated very quickly by using the following formula:

Per cent. yield=

$$\frac{G \times [100 - (S + L + B)]}{G + D + H} \text{ in which}$$

G = shipping weight of castings in pounds. This is 3,000 pounds for the sample casting whose cost calculation is illustrated on page 58.

S = metal losses in percentage of the total metal charged. This percentage is obtained from the average cost summary and it is item 39 on the sample copy given for illustrative purposes on page 49. S is 3.00% in this summary.

L = melting and foundry loss (all metal unaccounted for) in percentage of the total metal charged. This percentage is obtained from the average cost summary and it is item 40 on the sample copy for illustrative purposes on page 49. L is 10.00% in this summary.

B = slagged castings in percentage of the total metal charged. It is item 38 on page 49. B is 0.3% in this illustration.

D = weight of defective castings in pounds. The weight of a defective casting is the same as the shipping weight of a good casting. This weight is 600 pounds for the sample casting whose cost calculation is illustrated on page 58.

H = weight of heads and gates used on *both the good and the defective castings,* in pounds. This weight is 1,800 pounds for the sample casting whose cost calculation is illustrated on page 58.

The formula used for calculating the yield of a specific casting or castings made from a specific pattern can be stated in simple terms making it more easily understood. The yield is calculated by multiplying the shipping weight of the casting or castings (G in the formula) by the difference between 100% and the sum of the average percentages for metal losses (S), melting and foundry loss (L), and slagged castings (B). This result is then divided by the sum of the weights of the good castings (G), the defective castings (D), and the heads and gates used on both the good and the defective castings (H), which gives the yield.

In the above formula, the terms S, L, and B are constant, as they represent average figures taken from the average cost summary representing average or normal operations of the foundry. The other terms vary with the casting whose cost is to be determined. By substituting the proper figures for the letters in the above formula, the yield for the casting illustrated on page 58, is calculated to be 48.2%. The use of this simple method for determining the yield for a specific casting is illustrated later on page 53.

The cost of steel per net ton of good castings varies with the yield, and it includes two main items: the cost of metals (item 1

on page 48), and the conversion or melting cost. The cost of metals should be based on the market prices of the metals used for making the steel. The conversion or melting cost (this is item 2 less item 1 on the average cost summary, page 48) should be the average cost representing average or normal operations in the foundry. This average conversion cost should always be used instead of the actual conversion cost for any single month. It is calculated in the following manner by using for this illustration the assumed figures on the average cost summary on page 48.

	Average Amount Per Net Ton of Charge	Prevailing Cost Per Unit	Cost Per Net Ton of Charge
Labor	6 man hours	70c an hour.......	$ 4.20
Fuel	60 gallons	6c a gallon.......	3.60
Supplies			1.00
Furnace Repairs........			.90
Other Repairs in Metal Department........			.40
Total average conversion cost per net ton charged.			$10.10

In calculating the average conversion cost for electric furnaces the average kilowatt hours and pounds of electrodes per net ton of charge would be used in the manner illustrated above. Also the average cost per kilowatt-hour representing average operating conditions should be used.

To obtain the cost of steel for a specific casting, its yield is calculated from the formula given above, and the cost of steel can then be quickly calculated from the following formula:
Cost of steel per net ton of good castings =

$$\frac{100\,M - [P \times (100 - L)]}{Y} + P.$$

M = total metals and conversion cost per net ton of metal charged into the furnace. It is item 2 on the sample copy of an average cost summary illustrated on page 48, which should be adjusted with the market prices of metals.

L = melting and foundry loss (all metal unaccounted for) in percentage of total metal charged into the furnace. It is item 40 on the sample copy of an average cost summary illustrated on page 49.

P = value of recovered scrap in dollars per net ton of scrap. This price of scrap is item 3 on the average cost summary illustrated on page 48.

Y = yield of good castings in percentage of metal charged into the furnace. This is calculated from the formula for yield given previously.

The easiest and most convenient way to obtain the cost of steel for individual castings is to construct a table each month based on market prices of metals and showing the cost of steel for various yields. After calculating the yield for the casting whose cost is to be determined, reference to such a table will give the cost of steel per net ton of good castings. This table is constructed by using the formula given above. The following illustrates the use of the formula for constructing the table of steel costs:

Table 1

COST OF STEEL PER NET TON OF GOOD CASTINGS FOR DIFFERENT YIELDS

Yield	Cost of Steel per Net Ton	Yield	Cost of Steel per Net Ton	Yield	Cost of Steel per Net Ton	Yield	Cost of Steel per Net Ton
21	91.30	36	58.70	51	45.30	66	37.90
22	87.75	37	57.50	52	44.60	67	37.60
23	84.50	38	56.30	53	44.10	68	37.20
24	81.50	39	55.20	54	43.40	69	36.80
25	78.75	40	54.10	55	42.90	70	36.50
26	76.25	41	53.10	56	42.40	71	36.20
27	73.90	42	52.20	57	41.90	72	35.80
28	71.75	43	51.30	58	41.40	73	35.50
29	69.70	44	50.40	59	40.90	74	35.20
30	67.80	45	49.60	60	40.40	75	34.90
31	66.10	46	48.80	61	40.00	76	34.70
32	64.35	47	48.00	62	39.50	77	34.40
33	62.80	48	47.30	63	39.10	78	34.10
34	61.40	49	46.60	64	38.70	79	33.80
35	60.00	50	45.90	65	38.30	80	33.60

M in the formula, which is item 2 in the cost summary on page 48, is $28.14

L in the formula, which is item 40 in the cost summary on page 49, is 10.0%

P in the formula, which is item 3 in the cost summary on page 48, is $13.00

Cost of steel per net ton of good castings =

$$\frac{(100 \times 28.14) - [13 \times (100 - 10)]}{Y} + 13.$$

$$\text{Cost of steel per net ton of good castings} = \frac{1644}{Y} + 13.$$

By substituting values for Y (yield) from 21 to 80, Table 1 is the result.

The above procedure is for the regular carbon steel. The cost of alloy steel is obtained by adding to the cost of carbon steel, the additional cost of the alloys used.

(b) Overhead Rates

The method of establishing overhead rates and applying them when determining the costs of individual castings, should be standardized throughout the steel foundry industry. Uniform methods to be used by all the members of the industry are very essential if vast differences in costs caused by the use of different cost finding methods are to be prevented.

There are five main overhead rates to be used for calculating the cost of an individual casting, in addition to the cost of steel mentioned in the foregoing. These are: molding overhead, core overhead, cleaning overhead, annealing cost, and general overhead.

Molding Overhead: There are two rates to be used for applying the molding overhead to an individual casting, and both are used when calculating the cost of a casting. One is a percentage of molding direct labor, and the other is a fixed rate per net ton of good castings. All the molding indirect expense in the standard classification of accounts on page 32 with the exception of molding sand, material and supplies used in molding sand mixtures, sand mill labor, and pouring labor where hand shank ladles are used, are to be applied to a casting as a percentage of the molding direct labor. Therefore item 12 ($20.00) on the average cost summary on page 48, less the sum of items 8, 9, 10, and 11 ($3.40), divided by item 4 ($18.00), and the result multiplied by 100, gives one molding overhead rate of 92% of the molding direct labor in this example. The other molding over-

head rate to be used along with the percentage rate, is the sum of items 8, 9, 10, and 11, which in this case is $3.40 per net ton of good castings.

Core Overhead: The core overhead rate is established in a manner similar to the molding overhead rate, that is, the core department indirect expense is a percentage of the core direct labor. Item 13 ($6.65) divided by item 5 ($5.00) and the result multiplied by 100, gives a core overhead rate of 133% of the core direct labor.

Cleaning Overhead: The cleaning overhead rate is established in the same manner as the molding and core overhead rates, that is, the cleaning department indirect expense is a percentage of the cleaning direct labor. Item 14 ($12.65) divided by item 6 ($10.00) and the result multiplied by 100, gives a cleaning overhead rate of 126.5% of the cleaning direct labor.

Annealing Cost: The annealing cost is a rate per net ton of good castings to be applied to all castings annealed. It is item 15 on the average cost summary, which in this instance is $3.25 per ton of good castings.

General Overhead: Two rates are used for the general overhead expense defined in the standard classification of accounts on page 36; that is, the general overhead expense is divided into two rates and both of them are used when calculating the cost of a specific casting. One is a percentage of the combined molding, core, and cleaning direct labor, and the other is a fixed rate per net ton of good castings. The following items of the general overhead expense are to be applied to a casting as a percentage of the combined molding, core, and cleaning direct labor: insurance, taxes, depreciation, salaries, administrative expense, and selling expense. All the other items comprising the general overhead expense are to be applied to a casting as a fixed rate per net ton of good castings. Refer to the average cost summary on page 49 for the division of general overhead expense into tonnage charge and direct labor charge.

The rates for the general overhead expense like the overhead rates mentioned in the foregoing paragraphs for the productive departments, must be established from average costs representing

average operating conditions in each foundry. If it is assumed that the cost summary on page 48 which contains assumed figures represents average costs, the determination of the two general overhead rates is illustrated in the following: The sum of items 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36, is $36.50, and this divided by item 7 ($33.00) and the result multiplied by 100, gives one rate for the general overhead as 110.6% of the combined molding, core, and cleaning direct labor. Item 37 ($68.70) less $36.50 gives $32.20 per net ton as the other rate for the general overhead.

There is a certain minimum general overhead cost per ton for each foundry that should be taken into consideration when calculating the cost of a casting. It is to be used when the general overhead cost obtained by computing it with the use of the two general overhead rates mentioned above, is less than the established minimum general overhead cost per ton. Each foundry should establish its minimum general overhead expense per ton by taking its average general overhead expense in total amount and dividing this by the maximum number of tons of good castings that could be produced, taking into consideration the factors that limit the output of the foundry. If the average general overhead expense (item 37 on page 49) during average conditions of operation is $45,342.00 as shown on the average cost summary on page 49, and the average number of tons of good castings produced during normal conditions in the foundry industry is 660, it may be possible for the foundry to produce as much as 950 tons of certain kinds of castings. Therefore, the minimum general overhead expense to be used when calculating the cost of a casting is, in this example, $45,342.00 divided by 950 or $47.73 per net ton of good castings.

The above procedure illustrates the manner in which each foundry should use its own average cost data for establishing the cost of steel and the overhead rates to be used for calculating the costs of castings made from individual patterns.

Cost of Individual Castings

Knowledge of average monthly costs of making castings is not enough, and it is essential that further analysis of the business

be made by studying the costs of making castings from specific patterns. Without the information obtained from job costs, the foundryman has no guide to aid him in keeping the costs of making specific castings at a minimum or in eliminating from his business those jobs that cannot be made at a profit.

It is not a complicated procedure to get the actual and estimated costs of castings made from individual patterns. A full explanation of it is given here.

The following basic data must be obtained for each casting whose cost of production is to be determined: shipping weight, weight of heads and gates, weight or number of defective castings, molding direct labor, core direct labor, and cleaning direct labor. The molding, core, and cleaning direct labor are defined in the standard classification of accounts given on page 30, and it is very important that these direct labor data be correctly determined. The shipping weight, weight of heads and gates, and weight or number of defective castings, are the data necessary for determining the yield and consequently the cost of steel in the casting as explained on page 50. The molding direct labor, core direct labor, and cleaning direct labor for the specific casting, are the data required for determining the indirect and overhead expense applicable to the casting by using the overhead rates explained on page 54.

The method of calculating the cost of a casting or castings made from a specific pattern is illustrated on the page following which contains a sample job cost form. All figures in this example are assumed. The overhead rates and cost of steel are taken from the assumed data on the Monthly Summary of Cost of Production of Good Castings on page 48, and they are described in the section beginning on page 50.

In the case of alloy steel, an addition must be made to the cost of the regular carbon steel, to cover the extra cost of the alloys used.

If the amount of defective castings is added in the form of a percentage when determining the cost of castings made from a specific pattern, it should always be stated as a percentage of the

good castings. This percentage should never be a percentage of the total castings, meaning the sum of the good and the defective castings.

The yield for the castings described on the Cost Record following, is obtained by using the following formula described on page 50:

$$\text{Per cent yield} = \frac{G \times [100 - (S + L + B)]}{G + D + H}$$

The figures for S, L, and B, in this formula are obtained from the Monthly Summary of Cost of Production of Good Castings, and using the assumed figures on page 49, S is 3 per cent, L is 10 per cent, and B is 0.3 per cent. Therefore, the formula for yield is reduced to the following in this instance:

$$\text{Per cent yield} = \frac{86.7 \times G}{G + D + H}$$

Each foundry must establish this simple formula by using its own data for the terms S, L, and B, and it is usually desirable to insert it on the Cost Record for quick reference and use in calculating the yield for castings from a specific pattern.

The term G in the formula is the shipping weight of the castings and in the example on the Cost Record this is 3000 pounds. The term $(G + D + H)$ in the formula is 5400 pounds in the illustration. Therefore, the yield for the castings from this pattern is $\frac{86.7 \times 3000}{5400} = 48.2\%$

The cost of steel per net ton of good castings is obtained for these castings having a yield of 48.2 per cent by reference to the table on page 53. Each foundry must establish this table by using its own data and by using the method explained on page 52, since all the figures are assumed in this description. In this illustration the cost of steel is $47.11 per net ton of good castings.

Every casting should be charged with its share of the defective castings for the entire shop, since the average cost summary from which overhead rates are established contains the cost of the

defective castings. Whenever there are no defective castings from a specific pattern, or the actual percentage of defective castings from a specific pattern is less than the average percentage shown on the average cost summary used for establishing overhead rates, the average amount of defective castings in percentage of the good castings should be used in the job cost calculations. On page 49, the average amount of defective castings is $\frac{44.4}{660} \times 100$ or 6.7 per cent of the good castings. This percentage was not used in calculating the cost of the castings on the Cost Record shown on page 60, because the actual amount of defective castings exceeds the average of 6.7 per cent.

A suggestion is made that all castings, whether or not they require cores, be charged with a fixed minimum cost per net ton for indirect labor and expense in the Core Department. This would be in the nature of a "readiness to serve" or "demand" charge; and it would be used if the Core Department overhead for a specific casting obtained by calculating it as a percentage of the core direct labor is less than this predetermined minimum amount, and also when a casting requires no cores. Each foundry using this suggestion would be obliged to determine its own minimum Core Department charge per net ton of good castings.

The Cost Record on page 60 is merely a suggested form to be used. Some foundries may wish to have a column for "Total Amount" which would be used for inserting the total dollars expended for each item. This column of figures might be more convenient to use by some foundries, particularly for the various items of direct labor when it is desired to have these items include the good and defective castings. The form illustrated shows the costs of the direct labor items per piece and per net ton of good castings, and the direct labor costs for the defective castings are added as a percentage.

Actual Costs and Estimated Costs

The estimated cost of a casting and the actual cost of a casting are calculated in the same manner, except that the basic data are estimated in the former, while they are results of actual experience

COST RECORD

ACTUAL OR ESTIMATED

Customer	Pattern No.
Address	Drawing No.
Name of Casting	Date
Quantity	

	No. of Castings	Weight per Cstg.	Total Weight
Good Castings (G)	10	300	3,000
Defective Castings (D)	2	300	600
Heads and Gates (H)	12	150	1,800
Total Weight (G+D+H)			5,400
Yield $=\frac{86.7\times G}{G+D+H}=48.2\%$			
Defective = 20% of Good Castings			

PATTERN EQUIPMENT			
No. of Patterns	No. Cores per Cstg.	Kind of Pattern	Molding Method
Size of Flask			
No. Patterns in Flask			

DETAILS OF COST

	Cost per Piece	Cost per Net Ton
Steel 48.2% yield	7.07	47.11
Special Alloys		
DIRECT LABOR		
Molding		
Molders	1.60	10.67
Apprentices		
Helpers	1.20	8.00
Dry Floor Molders	.40	2.67
Dry Floor Helpers		
Defective Catgs. 20% of above	.64	4.27
Contingency 5% of above	.19	1.27
Total Molding Direct Labor	4.03	26.88
Core		
Coremakers	.60	4.00
Apprentices		
Helpers		
Defective Catgs. 20% of above	.12	.80
Core Break. & Cont. 10% of above	.07	.47
Total Core Direct Labor	.79	5.27
Cleaning and Finishing		
Flogging	.10	.67
Removing heads and gates	.30	2.00
Chipping	.45	3.00
Grinding	.25	1.67
Straightening	.15	1.00
Cleaning defectives		
Contingency 10% of above	.13	.87
Total Cleaning Direct Labor	1.38	9.21
Total Direct Labor	6.20	41.36
Forward	13.27	88.47

	Cost per Piece	Cost per Net Ton
Brought Forward	13.27	88.47
OVERHEAD		
Molding overhead:		
92% of Molding Direct Labor	3.71	24.75
$3.40 per Net Ton	.51	3.40
Core overhead 133% of Core Dir. Lab.	1.05	7.00
Cleaning overhead 126.5% of Clean Dir. Lab.	1.74	11.61
Annealing $3.25 per Net Ton	.49	3.25
General overhead:		
110.6% of Total Direct Labor	6.86	45.75
$32.20 per Net Ton	4.83	32.20
Minimum $47.73 per Net Ton		
Total Cost of Good Castings	32.46	216.43

SELLING SUMMARY

Cost of Castings	216.43
Special Charges	
Freight	
Returns and Allowances	
Machining Hazard	
Total Cost f. o. b.	
Profit	
Selling Price	
Profit in % of Selling Price	
Pattern Cost	

NOTE: All figures on this form are assumed.

in the latter. Slight errors in estimated data on which the calculation of the total cost depends, have a great influence on the total cost. Therefore such data must be carefully determined when estimates are prepared. It is essential that the estimated data be compared with the actual data when the casings are produced, as this procedure will improve the estimating practice and it will also enable the discovery of costly errors.

Profit

The astounding percentage of business failures clearly shows the necessity for establishing selling prices which not only cover the complete cost of doing business, but also include sufficient profit to enable the company to perpetuate itself and make new improvements. A company can be permanently successful only when the element of profit is given careful consideration before selling prices are established.

It is necessary when making quotations to include an amount of profit sufficient to insure returns which will be large enough to assist in payment of dividends during periods of business depression which occur from time to time.

It is also very necessary when establishing selling prices, to include an amount of profit in addition to that required for dividends during periods of depressed business, sufficient to provide for a consistent development of the business and for the maintenance of surplus reserves. This is a fundamental economic principle upon which the permanent success of any industry must be based. This principle is often disregarded to the detriment of the entire industry.

The answers to the two following questions are related to the subject of profit derived from the manufacture of steel castings. Do the foundry and its stockholders pay for making castings or

do they get paid for the efforts and capital expended in making castings? If they get paid for making castings, is their remuneration commensurate with the skill, risks, and hazards connected with the business?

The Schedule Fallacy

By J. J. Ewens,* Milwaukee, Wis.

Mechanically the foundries have kept pace with other industries in improving their product and method of manufacture. The use of production equipment and labor saving devices is widespread. The modern foundry compares favorably with other plants in the use of efficient equipment for economical production. It is in the merchandising of its product, however, that the foundry industry has fallen behind. The weakest spot today in the industry as a whole is unintelligent estimating and an obsolete system of pricing or selling castings. The unintelligent estimating is really the result of senseless pricing. If we rectify the method of pricing we will also improve our standards of quoting.

What Is the Sliding Schedule?

The present system of selling castings on a sliding schedule based on weight is unsound in theory, has been a costly practice, and should be abolished. By a sliding schedule based on weight

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is meant the prevailing method of billing castings according to a set schedule following the rule that the heavier the casting the lower the price. The ordinary schedule is divided into various weight brackets or divisions in this manner:

Under	1 pound			
Over	1	to	5	lbs.
Over	1	to	10	
Over	10	to	25	
Over	25	to	50	
Over	50	to	100	
Over	100	to	250	
Over	250	to	500	
Over	500	to	1,000	
Over	1,000	to	2,000	
Over	2,000			

A separate price is quoted for each weight bracket. The price schedules, of course, vary with different foundries and with different customers, but they all follow the rule of the heavier the casting the cheaper the price per pound.

This vicious system originated with the early foundrymen and has been in almost universal use since. It is only the terrific competition of the last few years that has forced the more progressive plants to probe deeper and deeper into costs and pricing policies which has succeeded in bringing about any diversion from the old established antiquated method.

The Adoption of the Schedule

When first introduced in the early days of the industry, the foundrymen used what they considered good logic in adopting the sliding schedules. In those days labor was cheap, very cheap, and raw material equally so. Cost keeping or finding was unknown. Molding methods were slow, extremely slow, and molding probably constituted the largest single item of cost. That being the case, the pioneer thought that his reasoning was sound when he figured, not having any cost data, that the heavier the casting the cheaper the molding, the lower the cost, and naturally the lower the selling price. Without taking the time now to point out the all too numerous weaknesses in the above line of

reasoning of the early foundrymen—there can be no gainsaying the following statement:—perhaps the early foundryman did have some justification for his schedule method; we cannot condemn him for trying some such scheme as he blindly ventured forth in a new untried, unknown field of industry. But today with the wealth of accurate, adequate cost data and cost systems available to any foundryman, the continued and widespread use of an archaic method of pricing the product constitutes a sad commentary upon the progressiveness and business ability of the steel foundry industry in general.

There is a certain amount of appeal in back of the pioneer's justification for the weight schedule. A half truth is always attractive and finds ready acceptance. It is for this reason that even today countless foundrymen will vigorously defend and attempt to justify the weight schedule. However, a careful consideration of all the items of cost involved in the production of a steel casting will show that the weight schedule is unsound and must go.

Anyone using a sliding weight schedule in pricing castings is saying in effect that the cost of a casting is primarily dependent on the weight. This is the foundation, the keystone of the arch, of the schedule user. And it is from this angle that we propose to attack the weight schedule. For verily if we upset the foundation we have upset the justification, and like the house built upon sand, the schedule user's argument crashes down.

Scope of Paper

Let us consider just what items of cost are involved in producing a casting, and as we weigh these items of cost let us also see if weight is the determining factor of cost. Let us look into the molding cost, including the design, whether intricate or plain; kind of pattern equipment, mounted or loose; and then coremaking, including the importance of kind of boxes, whole or half, single or gang; and finally into all the various items of cleaning cost. In short, as we consider in detail all these elements, let us remember that labor constitutes about one-half of the cost of a casting and let us see if weight is the deciding factor.

In discussing the cost of producing a casting, we plan to use the recognized principle of figuring the cost of a particular casting. That is, the actual direct labor charges of the three main departments of foundry production: molding, coremaking and cleaning, plus the actual overheads applicable to each department as determined by past experience and easily obtained from any decent set of books. To this, of course, must be added general works overheads and metal cost in accord with the yield of the particular casting, a detailed discussion of this not being pertinent at this time.

Cost of Small Orders

Besides the above enumerated items there is one more angle of cost that has recently received some consideration. I refer to the cost of handling small orders. In this respect attention is called to an article sponsored by the Steel Founders' Society of America and appearing in the October 1, 1927, issue of THE FOUNDRY entitled "The Cost of Handling Small Orders." The writer is in entire accord with this article which suggests that single or small quantity orders should carry a minimum service or handling charge of from two to three dollars to cover the cost of putting an order through the foundry. Of course, an order of any consequence is not subject to this service charge and in considering the cost of producing a casting we propose to eliminate the small or short order and consider the cost of a casting ordered in fair quantities.

Molding Costs

The first consideration in this analysis of what determines the cost of a casting is the molding. The molding cost per pound or per ton of a particular casting is dependent on several factors, not only on weight as our friends the schedule users would have us believe. One factor and probably the most important in determining molding cost is pattern equipment. For example, an ordinary floor job suitable for a 36 by 36 flask, if mounted on cope and drag boards suitable for jolt molding, will cost only about half as much to mold in comparison to the cost of running this job on the floor if the pattern is not mounted or cannot be readily mounted. Consider that for a moment—molding cost

doubled if the pattern is not mounted. The first questions a good foundryman asks when figuring on a new job are—What kind of pattern equipment will be provided? How is the pattern constructed? Not, how much does it weigh? Regardless of weight the nature of the pattern equipment is a prime factor in determining the molding cost per pound of a particular job.

Another consideration is the design of the casting. If it is intricate in design or requires a deep flask, the molding cost increases. On large castings especially, the requirements of the casting in service raise or lower the molding cost. If there is considerable machine work on the casting, so that dry sand molding is required, the cost is greater than if green sand molding could have been used. Of course, in determining the cost of molding, weight is not to be entirely disregarded. It is a factor. For example, a hundred pound casting in a 26 by 30 flask, other things being equal, will mold cheaper than a hundred pound casting in a 36 by 36 flask. But our point as just developed is that weight is not the prime or sole factor that controls the cost of molding. The kind of pattern equipment, the nature of the design, the requirements of the casting are all vitally determining elements of molding time. Clearly, weight alone is not the yardstick to use in measuring molding cost.

Core-Making

The second great division of foundry costs is coremaking. In the average foundry core costs average about forty per cent of the molding cost. On many castings, however, the core making costs more than the molding. That is because there is a wide variation in the size and number of cores in different jobs. For example, a fifty pound casting may have a single core costing five cents or a \$2.00 per ton core cost, while a five hundred pound casting may have \$3.00 worth of cores or a \$12.00 per ton core cost. Yet under the schedule system, the five hundred pound casting should be cheaper because it is heavier. What has weight to do with this? Such variations in core cost are completely ignored in the schedule system.

Core cost is dependent not only on the number and size of cores but also like molding cost on the kind of equipment. Are gang boxes or single boxes furnished; are they whole boxes instead of half; must rods be used; must the core be pasted;—all these factors enter into the question of core cost. A question more pertinent than how much does it weigh, is the question: how big and how many cores are in the job?

Cleaning

The third main division of foundry production, and the one which in most foundries carries the highest direct labor charge, is cleaning. Just as in molding and coremaking, so also in cleaning, weight alone does not determine the cleaning cost per ton. Quite a few variables determine the cleaning cost per pound of a particular job. The size of the heads and gates, for example, largely determine the cost of grinding, and their size does not vary directly in proportion to the weight, as would be necessary if the sliding schedule were correct. Grinding costs also depend on the location of heads. A lower piece work price can be named if the heads are located on flat surfaces, making grinding easy by affording a good bearing surface, than if the heads cannot be so placed. This depends, of course, on the design and requirements of the particular job, not on the weight.

Chipping and trimming costs also vary with the design. If a casting has numerous cores and if the prints are poorly matched, resulting in heavy fins, or if the parts of the pattern are not accurately matched, or if a mold has been nailed, chipping costs go up. All these "ifs," these contingencies, determine the cost.

Another important item of cleaning cost is welding. In this connection it is interesting to note how completely the weight schedule users' reasoning falls down. According to them, heavy castings have the lowest welding cost per ton. An analysis of cleaning costs, however, reveals that quite the opposite is the case. Any good cleaning man will tell you that there is less welding per ton on a properly rigged production machine casting weighing under twenty pounds than there is on a ton of five hun-

dred or one thousand pound castings. One reason for this lies in the fact that the majority of the small castings do not require any welding at all, but almost every large casting has some welding and many of them a great deal.

The removal of heads and gates is an expensive operation on steel castings. Acetylene necessary for cutting off large heads and gates is expensive. On the lightweight castings this is not necessary as the heads and gates can be removed either by flogging or else with a sprue cutter. In short, the cost of virtually every division of cleaning; the grinding, chipping, welding and removal of heads and gates, depends on the variations of the particular casting, not primarily on the weight.

Metal Costs

Having discussed molding, coremaking and cleaning, there remains only one more variable direct charge—metal cost. Metal cost per ton depends on yield in accordance with the rule that the higher the yield the cheaper the metal cost per ton. Here again the weight schedule theory falls down under scrutiny. With the exception of the extremely light castings, the yield is higher generally on small castings than on large castings. Heavy castings require larger heads and gates even in proportion to their increased weight. For example, our average yield on castings weighing around one ton is 58 per cent, while our average yield on casting weighing around twenty pounds is approximately 63 per cent.

We wonder if we have completely dispelled the delusion of weight determining cost? Does not a careful consideration of all direct labor charges accomplish this? We have personally estimated, checked, and figured costs on hundreds of different castings of all weights involving thousands of tons, and one of the cheapest jobs we ever figured was a twenty-eight pound hitch casting ordered in quantities of two thousand at a time. Yet, on a weight schedule, a casting in this range would be quite high priced. Now if the cost of a casting does not depend on weight, then it naturally follows that the selling price should not be based on weight. That being the case the method of selling castings on a weight schedule is fundamentally wrong in theory, results in

inaccurate, unsound prices and, consequently, is dangerous to use and should be abolished.

Proposed Improvements

The discarding of the schedule method of pricing raises the question: Upon what basis then shall castings be sold? The answer to this query has been suggested in our consideration of the defects of the schedule. It really involves the adoption of two practices. First of all the cost of handling small or short orders must be recognized and provided for. As foundrymen learn to price their product more intelligently, they will inevitably be forced to adopt a handling or service charge for orders up to about ten pieces on light castings. The present system does not begin to reimburse the foundry for the cost of running a small order through the plant. Why then should the foundries carry this burden? Even today some foundries are levying a two to three dollar service charge for small orders. The charge is legitimate and what we need is to make this practice universal. That would provide for small orders.

The large orders, and this involves by far the greater tonnage, would be sold on a special price for each casting basis. That is, every pattern number would have an individual price, either per piece or per pound. This method, of course, involves figuring the cost of each individual casting. To figure the cost on each quantity order job requires a simplified cost system, adequate timekeeping, and an accurate cost man who also understands foundry practice.

Cost Finding Systems

If a foundry is using the cost system of the Steel Founders' Society of America* and every steel foundry should be using that system, or one closely allied to it, it is not a very complicated task to figure individual costs. The following data must be compiled: weight of casting, weight of heads and gates, piece work molding prices, coremaking rates, cleaning room piece work rates, average amount of welding per piece, and any additional work which the particular job may require, such as straightening or

*This cost system outline will be found as A. F. A., 1928 Preprint No. 28-3.

trimming. With this data and with a knowledge of overhead burdens in each division of foundry work, as obtained from the cost system, the individual cost of a particular casting is quite readily obtained. All this may sound as though it involves a tremendous amount of detail and office work, but, in reality, once the system is organized and established it can be handled by one man. In our foundry, for example, over 92 per cent of our tonnage is figured individually, and we are one of the large jobbing electric steel foundries.

This method, of course, should also be used in estimating all new work, and it offers an excellent method of checking estimated costs with actual cost. For if an estimated job is obtained the actual cost is run on the job and compared with the estimate. This comparison cannot fail to improve estimating practice.

While steel foundries and steel castings have been emphasized in this article, due to the fact that the writer's experience has been mainly in steel, the underlying cost ideas advanced apply equally as well to other types of foundries. It is true that each division of the foundry industry has its particular cost problems but the fundamentals of foundry cost accounting are essentially the same for all foundries.

Better merchandising is the need of the foundry industry today. The cost principles and merchandising ideas advanced in this paper apply with equal force to all branches of the industry; steel, iron, malleable and the non-ferrous branches. We have stressed the production side of the industry and have neglected the selling end.

Summary

In summary, this paper has endeavored to prove that the practice of selling castings on a weight schedule should be discontinued, and in its stead a system of selling castings on a special price for each pattern be adopted. Then instead of blindly selling a casting at a certain figure, because it falls within a weight bracket, the selling price will be based on the actual cost of the particular job, a cost that takes into consideration all the variations and particular features of the particular pattern. Varia-

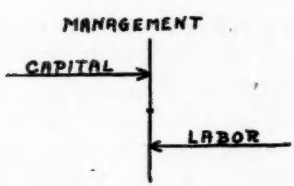
tions which we have seen, radically affect the cost either increasing or decreasing it. In short, it will be a sounder, better way of merchandizing our product.

Basic Principles of Management

By J. D. Towne, Dayton, O.

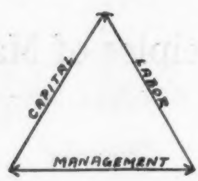
Foreword

Until within comparatively recent years the chief factors of Industry have always been Capital and Labor, each working in directly opposite directions, forming a "couple" as it were—two paralleling forces each acting against and counterbalancing the other to hold it in place—



with the result that Industry only maintained its equilibrium when each of these forces maintained equal pressure against the other. When either relaxed or strengthened, without the other following in the same way, Industry was disturbed or destroyed accordingly, and both Capital and Labor suffered in the same proportion regardless of which had been responsible for originally disturbing the balance.

Necessarily Capital and Labor must have the same interest, that of holding steady Industry, but just as necessarily they must each approach that interest from different directions, and consequently with different points of view. They have only recently found that, instead of directly opposing each other on every occasion, much more satisfactory results are obtained for all by allowing a third force, Management, to act upon each of the others, as a control, still holding their equilibrium, but changing the couple to a triumvirate. With this changed combination,



when either Capital or Labor may attempt to use undue pressure against the other, the new force of Management, by exerting its efforts properly, will counterbalance the other force and continue to hold this triangle of industry safe from collapse.

Management

Keeping actively in mind the relation of Management to both Capital and Labor, as well as to Industry as a whole, the following functions should be considered:

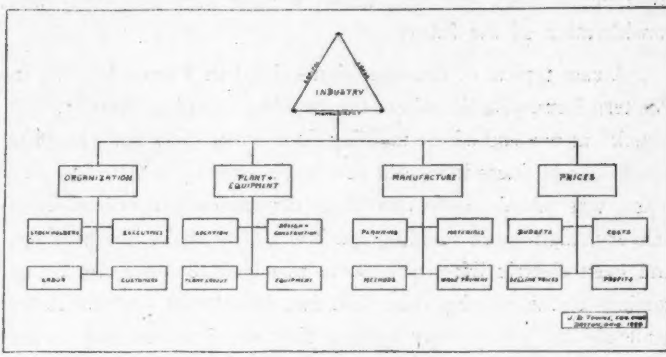
Management—
- a—Plans
- b—Executes
- c—Controls
- d—Develops

Without any one of these functions, Management cannot be operating properly.

a—Management Plans

As the first function of Management, planning constitutes the greatest difference between good Management, as now recognized, and past practices, general in many shops throughout the

country even today. Planning requires an outline, and consequently a study of each move to be made, regardless of the department, equipment, or individuals affected, in order to positively determine that a definite program is at hand, that the best possible methods are to be used in carrying it out, and that the costs are to be held within proper limits. In other words, Management, through planning, leaves nothing for under developed decisions, but builds up a program from intensive study of the subject, no matter whether that subject be the embarking upon a new branch



of industry, or the advisability of employing an additional common laborer in some one department.

While planning must be, and is applicable to every department and decision in any organization, it has been especially needed in most instances in handling manufacturing problems and keeping costs under accurate control. The best examples of planning in this sense are, 1—Plant Layout; 2—Production Scheduling; 3—Man Load Budgets; and 4—Expense Budgets.

a—1, Plant Layout

Plant layout is absolutely fundamental. How difficult future manufacturing problems are to be, as well as how low future manufacturing costs, depend very largely upon the efficient layout of any plant as a whole, and later upon the efficient layout of each specific department.

Where possible, the work to be done in any building should be carefully considered before construction work is approved. This has become a well recognized truth, and where buildings are now erected especially for the industries to occupy them they very rarely prove to be misfits; but it is estimated that over ninety-five per cent of our manufacturing buildings are occupied by industries different from the one originally intended, or else the size or circumstances of the original company has changed so greatly that the initial plans no longer suit, and the additional construction work has been added without sufficient study and consideration of the future.

A case typical of this condition existed in a brass foundry in Western Pennsylvania, where the cleaning room had been literally "stuck" at one end of the molding floor when the plant was quite small. As business increased new equipment, up to date in every sense, was added to the molding department; overhead sand delivery, high speed molding machines, new shake out gratings, and even electric lift trucks were provided to move the rough castings to the cleaning room, but that department was still in the same old out of the way corner, difficult of access, out of the natural routing of progressive flow of material, and the neglected equipment was so misplaced that the handling and rehandling of castings was costing several times as much as the actual necessary operations.

Our study showed at once that the department was misplaced. A room ideally located for the cleaning department was found to be the headquarters of the maintenance department. The locations of these two departments were reversed with beneficial results to each. A chain conveyor was installed to bring the castings in from the shakeout; and the sprue cutter, tumbling barrels, grinders, and inspectors were located in their natural order, reducing handling to a minimum. Through these changes alone, and before any incentive wage system was installed, the labor force was reduced exactly one-third, from twenty-one to

FOUNDRY PRODUCTION SCHEDULE

2,961 Total to cast

2nd WEEK OF 4th PERIOD.

WEEK ENDING April 9, 1927.

FLOOR	PATT. NO.	CAST	MON.	TUES.	WED.	THUR.	FRI.	SAT.	COMP.	PATT. STANDS	RECORD
									2588	New drawing	
23/24	2716	22		22					1148	1148	
	1846	16			16				1164	1561	(see note)
	1561	23				23			2725	New drawing - continue	
	2725	10					10				
									1506	1865	
25/26	1865	75	50	25					330	1410	31" flask
	1410	14			14				2368	2732	new drawing
	2732	45				15	30				
									2673	2673	
31/32	2673		180	180	180				2674	2674	
	2674		180	180	180				1214	1681	
	2716	200				100	100		1164	1279	
	1279	100				100			1164	1279	
	1280	100					100				
									1780	2521	
33/34	2127	160	160						2680	2505	
	2505	40		40					2680	2505	same cores 2505
	2616	15		15					2680	2616	" " "
	2629	22		22					1209	1963	
	1963	190		50	140				1780	2127	
	2128	140				140			2680	2629	
	2414	25					25		1209	1963	
	2739	110					110		1209	2739	continue
	1941	110							1209	1941	
	1940	110									
					50				1214	1422	
35/36	1422	200	150						2609	2785	
	2785	210		150	60				518	2788	
	2846	30			30				844	2800	
	2082	160				160			885	2001	
	2063	110					110		2816	Job shop (Graham)??	
	2831	28					28		2609	2785	continue
	2784	180					10		644	2002	
	2800	35							644	2800	New hub.
	2801	30									
			680	624	620	510	527				

J. M. [illegible]

PRODUCTION DEPT.

4-1-27, 12:30

TABLE 1

fourteen men, and the use of one electric truck discontinued.

a—2. Production Scheduling

Through production scheduling the old haphazard rule of thumb method of picking the next jobs by the foremen, is changed to absolute control through a carefully prepared schedule drawn up according to customer's actual requirements and specifications, rather than which jobs fit in best with the convenience or ideas of someone who cannot possibly work in close touch with the outside.

A production schedule should show not only all the jobs that are to be run during a given period, but also the machines or molding floors upon which each job is to be run, as well as the days, and quantities required. The accompanying production schedule, Table 1, clearly illustrates this type of schedule as applied to foundry practice. In these columns are shown, reading across, the molding floors scheduled, the pattern numbers, the total number of castings required from each pattern, the quantities scheduled for each day of the week, the master pattern number, the location of the pattern in the pattern vault, and finally a space for remarks or other notations.

This schedule is drawn up weekly by the production department and a copy handed to the foreman of each department affected on Friday for the following week. The two days' advance notice gives him opportunity to arrange his working force, equipment, material, etc., to suit the scheduled operation. The daily quantities scheduled for each machine or floor represent the proper daily productions for each job, allowances having been made to cover uncontrollable delays, fatigue, etc.

Besides this production schedule, the foreman receives also from the production department similar schedules, covering the week's operation, as to the number of man hours to be worked for the given production, and the expense budgeted for the operation of his department, so that he must be ever alert in order to keep every phase of his manufacturing within specified limits.

a—3, Man Load Budget

The man load budget is another detail of manufacturing

control that has received up to this time scant attention, although it is of even greater importance than production schedules, covering as it does the scheduling or budgeting of labor hours, both direct and indirect, according to the amount of work scheduled for any given period.

We figure accurately the amount of material necessary to manufacture the scheduled quantity of our product; the number and types of machines and other equipment required are readily determined in advance; during the last few years we have gradually been working to the budgeting of items of manufacturing expense; but it seems that the realization of the possibility of accurately budgeting and controlling the number of hours to be worked for any given scheduled production has been passed by, either without a thought or else with a feeling that it was too complicated to be readily accomplished.

In the foundry and machine shops of a large foundry company of the Middle West, over ninety per cent of the hours worked have been time studied, standard times set on jobs, whether direct or indirect labor, and a wage incentive in the form of bonus offered each worker for the proper accomplishment of his individual duty, within the time specified.

From these standard times, set from time studies on practically all jobs, a "Man Load" budget has been developed for every department. That is, from actual time studies the number of hours necessary to be worked in each department for any degree of production is calculated and shown upon master sheets, copies of which are shown herewith. These sheets include every department in the organization; administrative, sales, accounting, cost, engineering, purchasing, production, all shop departments both direct and indirect; maintenance, electrical, shipping, etc., and show the number of hours required to be worked per period, from a condition when the plant might be completely shut down (at which time besides office departments, it would also be necessary to keep all watchmen and some maintenance men working) on up, in steps of ten per cent increments of productivity, to one hundred per cent capacity.

The degree of productivity for the coming week is taken

Table 2

MASTER BUDGET—BASED ON PERIOD OF FOUR WEEKS (CORRECTED TO JAN. 1, 1927)—FOUNDRY GROUP MAN LOAD—HOURS PER PERIOD

Capacity, Per Cent	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Wheels	0	1200	2400	3600	4800	6000	7200	8400	9600	10800	12000
Pounds	0	270,000	540,000	810,000	1,080,000	1,350,000	1,620,000	1,890,000	2,160,000	2,430,000	2,700,000
Direct:											
Melting	0	270	540	810	1080	1350	1620	1890	2160	2430	2700
Core Room	0	640	1280	1920	2560	3200	3840	4480	5120	5760	6400
Molding	0	532	1064	1596	2128	2660	3192	3724	4256	4788	5320
Clearing	0	532	1064	1596	2128	2660	3192	3724	4256	4788	5320
Total Direct Hours	0	1974	3948	5922	7896	9870	11844	13818	15792	17766	19740
Total Direct Man Days	0	219	439	658	877	1097	1316	1535	1755	1974	2193
Indirect:											
Core Room	0	556	1112	1668	2224	2780	3336	3892	4448	5004	5560
Molding	0	804	1608	2412	3216	4020	4824	5628	6432	7236	8040
Cleaning	0	516	967	1410	1836	2246	2654	3064	3476	3882	4292
Total Indirect Hours	0	1876	3687	5490	7276	9046	10814	12584	14356	16122	17892
Total Indirect Man Days	0	208	410	610	808	1005	1202	1398	1595	1791	1988
Total Foundry Hours	0	3850	7635	11412	15172	18916	22658	26402	30148	33888	37632
Total Foundry Man Days	0	428	848	1268	1686	2102	2518	2934	3350	3765	4181
Foundry Pounds Per Man day	0	631	637	639	641	642	643	644	645	646	647

directly from the weekly schedules issued by the production department. Then the number of hours required in each department for this production is calculated from the master man load budget, and a memorandum handed to each department head and superintendent, giving the number of hours his department is expected to work during the coming week. These memoranda are issued not later than Friday afternoon, giving each foreman ample opportunity to complete his plans in advance.

A method of budgetary man load control as outlined herewith must necessarily have a solid background of accurately determined knowledge of each specific class of labor to be covered by the budget. If this background has not been developed under careful supervision and by use of accurate measures, it is impossible for the budget to be accurate in any greater degree. In other words, although the man load budget has always proven to be one of the greatest means of realizing savings through cutting costs, it necessarily should not be attempted until many preliminary steps have been accomplished.

It should also be held actively in mind that any system must be sufficiently flexible to be really valuable at a critical period, and in no event should be so stiffly bound by "red tape" as to be actually a hindrance at such times. For example, if special large orders are received for rush shipment, the problem of all concerned is action toward this end, which means that schedules, budgets, man loading, and all other plans must be altered immediately to suit changed conditions. Never permit a system to become a burden, either upon your own company or upon your customers.

a—4, Expense Budgets

The manufacturing expense budget is drawn up in a very similar manner to the man load budget, in master form, covering every separate item of expense, and showing the amounts of money set up as standards for each item at increasing steps in the manufacturing production. (Table 3.) From experience in foundries, machine shops, and other industries, it is recognized that budgetary control of manufacturing expense makes possible a saving, in the average plant, of at least fifteen to twenty per cent.

Table 3

PRELIMINARY MASTER BUDGET

(Foundry Group Only)

% Capacity...	%	20%	40%	60%	80%	100%
Pounds......	0	540,000	1,080,000	1,620,000	2,160,000	2,700,000
Expense Symbols						
X 1	$ 300.00	$ 350.00	$ 400.00	$ 475.00	$ 556.00	$ 556.00
X 2	......	60.00	120.00	180.00	240.00	240.00
X 3	......	2,400.00	4,800.00	7,200.00	9,600.00	12,000.00
X 4	......	2,970.00	5,940.00	8,900.00	11,880.00	14,830.00
X 5	100.00	200.00	275.00	350.00	425.00	500.00
X 6	......	900.00	1,800.00	2,700.00	3,600.00	4,500.00
X 7	......	13.00	25.00	37.00	50.00	62.00
X 8	50.00	150.00	220.00	260.00	340.00	390.00
X 9	......	63.00	133.00	200.00	266.00	333.00
X10	......	......	......	......	......	......
X11	......	870.00	1,740.00	2,610.00	3,480.00	4,345.00
X13	......	2,140.00	4,300.00	6,440.00	8,580.00	10,700.00
X15	......	3,265.00	6,500.00	9,800.00	13,060.00	16,325.00
X17	......	378.00	756.00	1,134.00	1,512.00	1,890.00
X20	......	398.00	798.00	1,198.00	1,598.00	1,998.00
X21	......	147.00	294.00	440.00	587.00	734.00
X22	......	540.00	1,080.00	1,620.00	2,160.00	2,700.00
X23	......	60.00	120.00	180.00	240.00	300.00
X25	......	440.00	880.00	1,320.00	1,760.00	2,200.00
X31	......	222.00	443.00	664.00	886.00	1,107.00
X32	......	184.00	367.00	550.00	734.00	917.00
X34	12.00	12.00	12.00	12.00	12.00	12.00
X52	1,800.00	1,800.00	1,800.00	1,800.00	1,800.00	1,800.00
X54	185.00	185.00	185.00	185.00	185.00	185.00
X55	100.00	100.00	100.00	100.00	100.00	100.00
Totals......	**$2,547.00**	**$17,847.00**	**$33,118.00**	**$48,355.00**	**$63,651.00**	**$78,724.00**
Cost per pound		.0330	.0307	.0299	.0295	.0292

An expense budget, when properly developed, gives control over every item of expense through the setting of standards and working to them, just as production standards, set from time studies, make possible the accurate control of any production job.

Each item of manufacturing expense must be analyzed and studied to determine how and why it varies, whether its variations are controlled, for example, by shop production (as "Sand" in a foundry would be), or by hours of labor worked (as "Supervision" or "Payroll" would be), or by square feet of floor space occupied (as any general department "Lighting" would be). It has been determined by one of the leading manufacturers of automobile trucks that over eighty per cent of all their manufacturing expense varies in direct proportion to the total man hours worked.

When the unit of variation has been determined for each expense item, its performance of past years is tabulated and studied, and from such exhaustive analyses it is possible to very accurately determine the proper standard of expense for each item at varying degrees of productivity, after which master expense budget sheets, such as shown herewith, are readily compiled.

A memorandum of the expense budget for the following week, covering each item in detail, is handed department foremen on Friday afternoon and a follow-up, identical with that described later, for the man load budget, is also carried out through daily expense reports secured from the cost department. This daily check on manufacturing expense gives an immediate follow-up on any item that may be beginning to run wild, and teaches department heads the necessity of watching every item entering into costs, whether large or small.

b—Management Executes

The executive, or administrative, function of Management has been recognized, in name at least, since the beginning of In-

dustry; but an entirely new responsibility has been placed upon it by its antecedent, planning. Previously the executive acts of Management have been largely based upon "judgment," which is only another name for "guesswork," with the result that the organizations with the best guessers at the top have been the successful ones.

The careful study of problems before decisions are required, has removed much of the element of chance from business, and this one fact perhaps more than any other has been responsible for the remarkable growth of Industry during the last twenty years.

It should be understood that the executive function of Management does not parallel the recognized duties of an executive. An executive in any industrial organization must manage, in the true sense of the word, to the extent of responsibility given him. He must, a—Plan, b—Execute, c—Control, and d—Develop to the extent of his limitations in the organization, but the strictly executive function of Management is merely the issuing of orders, the arriving at definite decisions, after the plan has been carefully made.

In many cases the executive function has not been developed. We are all familiar with the type executive who cannot "make up his mind," from whom it seems almost impossible to secure any decision, and who is ever ready and anxious to permit his subordinates to carry the responsibilities that rightfully are his. The only means of arriving at prompt and definite decisions is through planning, and, consequently, the executive who hesitates or dodges his responsibilities in this respect, is the executive who either has done no planning at all, or else has not studied his plan sufficiently well.

c—Management Controls

In considering the several functions of Management it is most difficult to define any one without encroaching upon the fields of the other three, so inseparable and dependent are each of the four, one upon the others. After the plan has been made and the decision to execute put into effect, it is then necessary

for Management to Control the situation in order that the work may proceed according to plan; and, consequently, we find, especially in considering the function of Control, that "Plan," "Execute," and "Develop" are all so intertwined that we cannot keep them entirely separate.

c—1, Control Through Budgets

Under the heading of Management Plans, the building up of the man load budget has been described in some detail, as well as its issuance to the department heads,—which is really the executive function,—and from this point on control must become effective.

Although the issuance of the instructions to the foremen is a very necessary step, the real control of the situation comes from the "follow-up." The comptroller receives at the beginning of each week, in the foundry organization previously referred to, a man load control sheet for both the foundry and machine shop divisions, each week, listing on the left all departments in the particular group it covers, and the total hours budgeted to be worked in each department during that week. Seven columns to the right of the departments provide space in which to show the actual hours worked daily in each department; an additional column is for the total weekly hours of each department; a final column will show the budget efficiency—that is, actual hours worked as compared to hours budgeted.

The actual daily hours worked are posted on this sheet before ten o'clock each morning and a short study of these figures in comparison to the budget figures shows at once the departments that have worked too many hours, and enables the comptroller to keep the situation in every department well in hand by checking into discrepancies while the circumstances and conditions are still fresh in the minds of all concerned. Table 4 shows copies of these man load control sheets.

This form, the real follow-up work sheet of the man actually in charge of seeing that the man load budget is lived up to in every department, should be kept posted up to date at as early an hour as possible each day, and must always be at hand to give

Table 4

FOUNDRY "MAN LOAD" SCHEDULE: 2640 WHEELS—WEEK ENDING APRIL 9, 1927

Depts.	100%	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Total	Per Cent
Furnace	421	....	88.5	77.8	80.0	75.5	73.8	90.5	486.1	87
Core Room	1411	....	268.0	300.8	299.8	288.5	262.0	102.0	1521.1	110
Core Room (Indirect)	1224	....	160.8	174.2	167.5	159.8	132.0	85.5	879.8	110
Molding	1171	....	264.0	274.0	255.5	270.0	274.5	.....	1338.0	92
Molding (Indirect)	1771	....	352.8	367.5	382.2	345.5	320.8	107.8	1876.6	92
Cleaning	1171	22.5	255.2	255.0	257.5	266.2	242.0	151.0	1449.4	76
Cleaning (Indirect)	950	9.0	238.0	233.2	239.0	228.8	235.5	157.8	1341.3	76
Pattern Shop	680	22.8	124.5	144.5	149.8	117.8	108.5	64.5	732.4	93
Millwright	615	78.0	88.5	101.5	119.5	95.8	87.5	109.8	680.6	91
Electrical	280	1.0	42.8	40.0	58.5	40.8	40.5	63.5	287.1	98
General	690	44.0	100.8	94.2	96.5	92.2	79.0	67.0	573.7	120
Totals	10384	177.3	1983.9	2062.7	2105.8	1980.9	1856.1	999.4	11166.1	93
Cumulative Totals	....	....	2161.2	4223.9	6329.7	8310.6	10166.7	11166.1	.....	..
Cumulative "Man Load"	....	44	1924	3804	5684	7564	9444	10384	.....	..
Good Wheels Poured	....	....	480	544	497	429	386	329.4	51 lbs.	..
Cumulative Total	....	....	...	1024	1521	1950	2336	.....	.....	..

Note—89% of "Man Load" Basis.

at a moment's notice the comparison between actual conditions as opposed to what the budget shows should be. As this form must always be conveniently handy, we favor a size that will fit nicely in a pocket binder.

An accurate budget and immediate follow-up such as this on all labor hours worked in an organization brings under absolute control the item of expense that represents by far the greatest amount of money in the majority of industries. At the same time each department has two very definite goals that it must attain, or else explain with excellent arguments the cause of the failure; a—a given production must be attained, and b—not more than a stated number of hours may be used in reaching this production.

c—2, Material Control

Another phase of the control function is material control. The absolute waste of material through lack of control in the average manufacturing industry is astounding. Material is wasted in process of manufacture; material is wasted in the stock room; material is wasted all over the plant through carelessness. Walk through the average foundry, for example: the shovels, riddles, flasks, bottom boards, bands, grinding wheels, etc., permitted to lie about is unbelievable. Besides these things there are usually pulleys, belting, steel bars, miscellaneous tools, and numerous other things, accumulating in various corners of the plant, waiting to be used if any one chances to remember at the proper time that these things are in that particular out of the way place instead of buying new, but representing an investment that should be put to better use.

Material control frequently has been surrounded by so many vari-colored printed forms, elaborate instructions, and consequent red tape that many practical men feel, of the two evils, they prefer to continue with the old "hit or miss" method. The color, printing, number of forms, length of instructions, etc., are all unimportant, but it is absolutely necessary to keep very careful and complete control over all material constantly if we are to avoid accumulating an inventory of tremendous proportions.

As is true of any other detail of good management, material

control should be kept as free from red tape, and as easily understood and maintained as possible. Keeping this in mind, the essential points of Material Control are as follows:

a—To record location, description, and unit of measurement of each item of material.

b—Keep accurate record of use and disposition of stock, crediting and debiting proper jobs as used.

c—Determine what quantity of each item should be the minimum to have on hand at any time, and in what quantities orders for stock should be placed.

d—Give perpetual inventory of stock on hand, in both quantity and money value.

e—Record complete history of each item of material from time ordered until used in its ultimate location.

In developing definite control over all manufacturing conditions the fundamental ideas are the lowering of costs, the increasing of production, and the accompanying increase in net profits. But aside from these very natural and proper incentives we should not lose sight of the fact that such control also brings very real benefits to our customers. Quantity and quality specifications can be more easily realized; rush orders and special delivery dates can be promised with accuracy; the frequent complaints from customers of slowness in deliveries are reduced to a minimum; and most important, when costs are materially and definitely lowered the customer is sure to also benefit ultimately through lowered sales prices.

d—Management Develops

As was stated at the beginning of the section on "Management Controls," it is almost impossible to consider one function of Management without including one or more of the other three. In the case of Development, this function is in reality the outgrowth of the other three. New development along any lines cannot be successfully completed without the planning, executing, and control functions having properly preceded; and again, rarely can planning, executive and control be properly carried through without resulting in the development of improved man-

ufacture, men, or methods.

Management works both ways from development. Starting with planning, the other functions lead up to development; as new developments are made, new plans are necessary and the cycle has again started. Development represents the progress of Industry; it is the result of thought, usually of real mental effort of the men connected with Industry. Not alone the thought of men who are employed in the research or experimental departments of organizations, and assigned particularly to development work, but even more especially is development frequently the thought of superintendents, foremen, and ordinary workmen, and consequently in order to develop improved manufacture, Management should first develop improved men.

D—*1, Development of Men*

It is frequently possible in handling groups of skilled workers to so arrange their method of compensation that not only will increased production and lowered costs result but, of even greater value to the men themselves as well as to their company, each member of the group has a decided incentive to develop himself mentally; that is, to use his own initiative in regard to the work he is handling in order to develop the most efficient method of operation, and incidentally earn an increased compensation.

A splendid example of the possibilities of this plan as applied to a pattern shop, in connection with a foundry organization, follows. The customary attitude of foundrymen toward the pattern shop seems to be that it is a necessary evil, a hopelessly heavy burden, with which so little can be done in the way of improvement that the only hope is to make sufficient savings in the other departments so that the pattern shop will not sink the entire plant.

This attitude is to be regretted for the pattern shop, as well as any other necessary department in any kind of manufacturing industry, if managed properly is just as great an asset to its company as any production department, and the following outline has not only brought decreased pattern costs but has also

developed men, who are ever alert to take advantage of their possibilities, and to use their minds to improve the operating conditions.

Bonus Chart for Pattern Shop and Pattern Storage
(Department 1-P)

The following bonus will be paid in addition to and entirely independent of hourly wages, based upon the efficiency of the entire group when performing duties as outlined under the conditions as specified in this chart. This is a temporary bonus chart subject to revision if, as, and when changed conditions may so require.

The bonus paid on this chart is a voluntary contribution by the Company in consideration of improved performance as reflected through increased efficiency, improved quality, good discipline, and lowered costs. Failure to maintain these conditions may result in the temporary or permanent discontinuance of this bonus for any or all of these participants who fail in these respects.

Equipment

1—16" Bentel & Margedent Jointer
1—24" Oliver Thickness Planer
1—30" Oliver Bandsaw
2—42" Post Lathes
1—14" Disc Sander
1—24" W. F. & John Barnes Co. Vertical Drill Press
2—No. 1 Oliver Bench Trimmers
1—Large Fox Bench Trimmer
1—No. 2 Victor Emery Wheel
1—5/16" Electric Hand Drill ("Handy")
1—¼" Clark Automatic Electric Hand Drill
Miscellaneous Hand Tools, Drills, Taps, Chisels, Gaugers, etc., etc.
Work Benches, Stools, Cabinets, Screws, Nails, Wax, Filets, Bins, Lockers, etc.

Duties

The pattern shop group is expected to take care of the making of all new patterns and core boxes, either wooden or metal; make all alterations, repairs and changes on old equipment; fasten all patterns and core boxes properly to molding and core making machines ready for operation, and remove same when jobs are completed; store all patterns and core boxes safely and carefully when not required in Pattern Shop or Foundry; and in every other way assume all responsibility for the proper dimensions, details, safety, and care of all patterns and core boxes.

The pattern shop foreman will instruct his men thoroughly covering the work to be done. The man, or men, receiving such instructions (whether necessary or not for them to leave their regular work points), shall produce required materials or patterns, etc.,—if any, obtain all necessary tools and equipment needed to properly complete work as specified, and proceed at once to location where work is to be done. This work must be performed as quickly as possible and in a thoroughly efficient manner.

Upon completion of specified work, all tools and equipment must be returned to their proper places, and the man, or men, report at once back to the pattern shop foreman for instructions on the next job to be done. It will be the duty of the pattern shop foreman to keep a job ahead of each man at all times,—to properly plan the groups of work that they may be done with no delays between jobs,—and to cooperate with the men in every way possible, in order to cover the greatest amount of jobs in the least amount of time. Bonus as paid by this chart will be determined by the efforts of the Pattern Shop Group as a whole; this will require cooperation on the part of each and every man.

Basis for Bonus

The basis upon which the bonus covered by this chart will be figured is the total pattern shop expense (covering all duties as outlined above, and including all department expense, as well as all miscellaneous pattern expense throughout the entire plant), per one hundred pounds of good castings poured in the foundry, figured at the close of each regular four weeks' period.

All expense, in any department, caused by errors, delays, etc., in the pattern shop, will be charged directly against pattern expense, instead of against the department in which the expense was incurred.

100% Eff. =	$0.090	Total pattern expense per one hundred pounds of good castings poured.		
95% Eff. =	.095	"	"	"
90% Eff. =	.100	"	"	"
85% Eff. =	.106	"	"	"
80% Eff. =	.113	"	"	"
75% Eff. =	.120	"	"	"

Bonus for the several classes of labor will be figured in the following bonus classes:

Pattern makers	Bonus	Class	8
Set up man	"	"	5
Pattern Storage man	"	"	5
Apprentice boys	"	"	2

Method of Computation

Having the total number of good castings (expressed in hundreds of

pounds) produced in the foundry for any given four weeks' period, and the total pattern shop expense (as outlined above) for the same period; by dividing the total number of hundreds of pounds produced into the total pattern shop expense, the total pattern expense per hundred pounds of good castings poured will be determined.

From the clock cards for the four weeks making up any given period will be taken the number of hours actually worked by each man, and every member of the pattern shop group will be paid his bonus, in the proper bonus class, based upon his individual hours worked.

Example

Suppose the foundry production of good castings for one regular period of four weeks shows a total of 1,651,000 pounds, and that the total pattern expense for the same period has been \$1,750.00. By dividing we find \$0.106 to be the pattern expense for each hundred pounds of good castings poured.

Then—dividing \$0.106 into \$0.090 (the 100% figure), the efficiency of the group is determined as eighty-five per cent (85%). If each member of the group has worked full time (198 hours per period), by consulting the chart below we find that their bonus will be as follows:

Pattern makers	\$27.72
Set up man	17.33
Pattern storage man	17.33
Apprentice boy	6.93

Bonus Chart

% efficient 198 hours	Bonus Class 8	Bonus Class 5	Bonus Class 2
75	\$19.80	\$12.38	\$4.95
80	23.76	14.85	5.94
85	27.72	17.33	6.93
90	31.68	19.80	7.92
95	35.64	22.28	8.91
100	39.60	24.75	9.90

Differentials per cent—198 hours:

Bonus Class 8	\$0.792
Bonus Class 5	.495
Bonus Class 2	.198

N. B. No bonus will be paid for any efficiency lower than 75%. That is, no bonus will be paid when pattern expense is higher than \$0.120 per hundred pounds of good castings poured.

Closure

While considering in the preceding pages first, the three forces of Industry as —

a—Capital
b—Labor
c—Management

and then, taking Management apart from its two associate forces, we found that Management, in Industry,

a—Plans
b—Executes
c—Controls
d—Develops

We have analyzed these functions in some detail, and determined in what way each acts upon Industry as a whole, but it is well before closing to consider Industry itself, of what it consists, how it is built up, and consequently bring out the many phases of Industry upon which the force of Management acts, through each of its four functions.

Industry

Any manufacturing Industry is built up of—

1—Organization
2—Plant and Equipment
3—Manufacture
4—Prices

Then—

1—Organization (Personnel)
  a—Stockholders
  b—Executives
  c—Labor
  d—Customers

2—Plant and Equipment
  a—Location
  b—Design and Construction
  c—Plant Layout
  d—Equipment

3—Manufacture
- a—Planning
- b—Materials
- c—Methods
- d—Wage Payment

4—Prices
- a—Predetermined Costs (Budgets)
- b—Actual Costs
- c—Selling Prices
- d—Profits

These several sub-divisions of each of the four chief phases of Industry are, of course, again sub-divided at least once or twice in actual practice, varying according to the size and kind of Industry considered.

Management

Just as there is no question that Management is a very essential part of Industry, so likewise there can be no question that every member of any organization who plans, executes, controls and develops in connection with his work, no matter how confining his limitations, is a very positive part of Management.

Management is too frequently considered by individual members of organization as something completely apart from themselves; something that is placed entirely in the hands of one man, or a small group of men, that very certainly affects them, but of which they cannot consider themselves a part.

We have been hearing for a number of years of various "systems" and "methods" of management, each of which is evidently the panacea for all Industry. But the most successful form of Management, for Industry itself, is the Management that can secure the cooperation of every member of the organization; that can make every member feel that Management is not something to be feared and looked upon in awe; but that it is really made up of the members themselves, and that Management's success is entirely dependent upon them, upon the success with which they

- a—Plan
- b—Execute
- c—Control
- d—Develop

The American Boy in the Foundry

By F. J. McGrail, Three Rivers, Mich.*

Not the least of the problems involved in connection with the successful and profitable operation of a foundry, is the question of how we are going to obtain our molders for the future. For many years the writer has realized that one of the greatest problems confronting the foundry industry is the future supply of skilled molders, which at present is inadequate to fill depleting forces, to say nothing of meeting the demands of an important expanding industry, and we have emphasized particularly herein the vast importance of a special training for apprentices who in time will help to replenish the rapidly diminishing supply of molders.

From the writer's experience in the foundry game for more than a third of a century, let us call your attention to a few simple facts in the history of the development of the industry since we first entered a foundry to learn the trade of molding. In Providence, R. I., where our apprenticeship was served, every industrial plant of any importance had a waiting list of boys names who wished an opportunity to learn the trade of patternmaker, molder, boilermaker or machinist.

It was extremely difficult to get a chance to learn any of the above mentioned trades at the time of which I speak, because applications were usually made by boys at least a year be-

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fore they left the grade schools, and as many of the boys' parents or relatives were working at some of the trades referred to, it was hard indeed for a boy without influence to get the opportunity to learn a trade of any kind.

In the early nineties we saw almost exclusively the employment of American born boys in the foundries, and nearly all American born men. The boy who learned a trade at that time was developed somewhat slowly, we admit, but nevertheless surely, and as all forms of shop discipline were pretty strict the boy who attended to his work eventually reached a high degree of practical intelligence. It is from many of the boys who were developed at that time that we have drawn a large number of our foundry executives who are holding responsible positions in many of the leading foundries today.

This further emphasizes the fact that it will not only be necessary to train boys to become proficient molders, but we will have to devise ways and means to establish a system of training the most capable of our molders by technical instructions combined with their practical experience for our future foundry executives. To put the statement more concisely, we will be forced to adopt methods which will enable us to graduate some of our most proficient mechanics from the sand heap to the position of foreman or superintendent.

The boys of this early generation that I am describing acquired a considerable amount of skill from their fathers or other men in the foundries who had worked at the trade long enough to teach them intelligently, and it was a rule in most foundries at that time that the coremakers and molders must properly instruct apprentices whenever they were asked to do so. That is a spirit that we hope to see revived and inculcated in our foundries in the very near future.

Where the Skilled Molders Came From

As the manufacturing industries in New England and other parts of the country grew to larger proportions the supply of American born help became smaller. It was necessary for us to call for skilled molders from across the water to come to America

to relieve the situation. The first foreign molders that came to our city were from England, Ireland, Scotland and Wales. We believe you will agree with the writer that in these older countries were many excellent workmen who emigrated to our shores, but, unfortunately, the supply was soon used and as there were no emigration laws in effect at that time, we began to call on Norway, Sweden, Denmark and Germany for skilled molders. In all of the above mentioned countries there were schools and excellent systems of training apprentices, in most cases seven years being the usual period of time served, and, consequently, we were able to obtain many highly efficient molders.

The Advent of the Molding Machine

It was not many years, however, before the supply from all of the above mentioned countries became exhausted. There was nowhere else to turn for aid, and how to keep the foundries running when business was good became a serious problem. It was at this time that many of the men who operated foundries were forced to get busy to determine what could be invented in the line of labor saving devices to develop a means of utilizing unskilled labor where skilled workmen had formerly been employed.

The molding machines which we see in use in many of the foundries today are the result of many ingenious men who gave a great deal of time and study to their development, and the molding machines in a large measure did help to make good the deficiency, but it is a well known fact that mechanical appliances for molding, no matter how carefully designed, will never solve the problem confronting the industry, because any molding machine made has a limited field of usefulness. We firmly believe in the molding machine and we would not wish to attempt to operate a foundry without them. However, the need for skilled molders and foundry executives will never diminish, but will surely increase in proportion to the expansion of our industries.

What Is the Matter With Our Foundries?

As we cannot evade the question we may as well face the fact that the foundry is no longer attractive to the American boys, and how to make it interesting and attractive in the near future is a

problem that we must at least attempt to solve. What does the average foundry offer to a young man today as an inducement to learn the trade of a molder? It is a lamentable fact, and a sad commentary on the situation that they offer nothing. For more than twenty-five years, to the writer's certain knowledge, the majority of the foundry proprietors in the United States have done all they could to discourage the American boy from learning a trade, and now they are paying the penalty for this omission, and they will pay a heavier toll in the very near future if they do not use drastic measures to correct the situation.

The average foundry owner, or manager, when he looks at a bad casting will howl his head off and complain bitterly about the scarcity of good molders, yet he may be just as guilty as his neighbor in denying American boys a chance to enter his foundry and learn the business. Plant managers and foundry owners will tell you that they cannot be bothered with apprentices, because, as it frequently happens, about the time the boy becomes proficient he seeks employment elsewhere at a higher rate of pay. Unfortunately, this is true in many cases, but it is also true as many of you know, that many boys have actually been driven out of the foundries because they were being exploited by being kept on one kind of work too long, which condition the boy had sense enough to know would lead to arrested development.

The only solution to the above problem that we know of is cooperative training for foundry apprentices who should be properly indentured. If foundrymen could be made to understand and realize the importance of cooperative training, the better it would be for the foundry industry in general, because there would be more boys to fill the various foundries, and if they quit before the completion of their apprenticeship, it might be well to look within your own organization for the real reason.

Some Foundries We have Seen

One thing in particular that may induce the American boy to learn the trade of molder today is that we have much better foundries to work in than we had thirty years ago. We learned our trade in a good shop and under excellent working conditions,

but when our apprenticeship was served and we began to ramble, we surely bumped into some pretty tough joints where pig iron was made into castings of various kinds. We have pounded sand in foundries that were on the fifth floor, and we have hung up our coat and shirt in several foundries that were located in the basement where a ray of sunshine never penetrated and one had to work with a kerosene torch all day. Thanks to our factory laws, such foundries cannot be operated today.

Most of the foundries built during the past decade are light and airy, being ventilated by forced draught which keeps pure air constantly changing and circulating. They are also well equipped with washrooms, with hot and cold running water and shower baths. Somewhat different from the old days when we heated our own water to wash in by dropping a hot sprue in a water bucket.

How to Get the Right Kind of Boys

In order to attract the right kind of boys for our foundries we will have to furnish them with a substantial incentive to obtain their best efforts. After many years of careful study on this subject, we have come to the conclusion that the boy's interest in his foundry job is in direct ratio to the amount of money that you will put in his pay envelope at stated periods. We have hired many boys at various rates of pay, but when they were put on productive labor and were making castings they became disgusted and quit because their hourly rate of pay was not as high as that of the common laborers.

Baseball, basketball teams, gymnasiums, swimming pools, bowling teams, brass bands, welfare associations, and old age pensions help wonderfully in attracting a better class of labor to an industrial plant, but it is seldom that any of these appeal to the average boy because he does not realize the benefits to be derived from them.

Some of you may say: "Put the boy on piece work so that he can earn more by doing more." We do not believe that answers the question satisfactorily. We believe that piece work for indentured apprentices is detrimental to their general welfare as we feel

that their better interests will be served by working on a straight hourly basis for the period of their apprenticeship, as piece work for them might put a premium on carelessness. Do not infer from this statement that we are opposed to piece work. We are firm believers in piece work for all foundry operations except as noted above.

Payment of Apprentices

The rate of pay for indentured apprentices will depend largely upon the locality. Large cities usually pay more than small towns. We believe that an apprentice should serve at least four years, and should work a probationary period of six months at a fixed hourly rate to determine if he would like to continue at the trade. If he is considered good material and is physically fit he should receive an increase of pay for the second period of six months.

When an apprentice to the trade of molding has completed his first year of service satisfactorily, we believe that a fixed hourly rate of pay should be abandoned and his wages set by the head of the department. This method will furnish a better incentive for the boys, some of whom at the end of their first year will show greater ability than others. The boy that is worth more should be paid more. Boys of this type are the kind that should be encouraged. The apprentices rates of pay should be based upon attendance, ability, application, deportment and school standing if school work is used in conjunction with their course of foundry training.

Technical Training for Apprentices

We believe that school work is a valuable adjunct to a foundry course, and if a foundry is situated in a place where technical training may be had it would, of course, enhance the value of the apprentices. If the boys in training cannot have the advantage of a school, competent instructors could be hired if the number of apprentices in a shop warranted it. A technical adviser could teach the boys from several shops if necessary. If none of these plans are feasible, there are the evening public schools, and the correspondence courses. There are many ways in which the boy can educate himself, but first of all you must get him interested

in his work for the simple reason that you cannot be successful in a job if you do not like it.

Ages of Apprentice Molders

It is a debatable question as to what is the best age at which to start a boy in the foundry business. "Get them young," is a good plan, but as most foundry operations are somewhat strenuous, we believe that boys 18 to 20 years of age are to be preferred as the best age for boys beginning work in the foundry. Some boys between 16 and 18 years old are fairly well developed and large for their age, but the boy of 18 or 20 is more mature and at that age has about made up his mind what kind of work he would like to do. Boys living at home are to be preferred, but we have helped to train a considerable number of boys who were self-supporting when they were 18 years old.

Ratio of Apprentices to Molders

Most of the skilled molders with whom the writer is acquainted are between 45 and 55 years of age. As the average age of death of all occupied males is 48 years it is quite evident that a considerable number of foundry apprentices should be in training now to replace the molders whose expectancy of life is not very long. We believe that a ratio of one apprentice to each 4 molders would be about right to help fill the proper quota of skilled molders we should have.

Method of Instruction

We believe in the group plan of training foundry apprentices. Choose a few of the best molders in your shop, add enough to their hourly rate to make the job interesting and have them supervise the work of one, two or more apprentices. Of course, it would not be fair to expect a full day's work from an instructor thus employed. The average foundryman will not take kindly to this arrangement on account of its cost; he will tell you that competition is too keen to permit it, but if other foundries in the same city were doing the same thing they would all be on an equal basis, which brings us again to the cooperative plan of training American boys in the foundry business.

Bad castings also cost a lot of money when made by handymen not properly trained. We have technical advisers in many industrial plants, but nothing is being done along educational lines for the foundries except in Milwaukee and a few other places. It's an old saying that: "whatever you need in your foundry you pay for it whether you buy it or not."

Recommendations

We recommend the payment of a bonus of $100 or more to the graduate apprentice upon the successful and satisfactory completion of his foundry course, and we favor the granting of a suitable certificate to the graduate apprentice to be properly signed by the works manager, foundry superintendent, and educational director.

We propose to institute a plan of instruction at the Sheffield Works of the Fairbanks, Morse & Company, Three Rivers, Michigan, to teach the American boy a trade that he will be proud of in his later years. Briefly outlined the course will be about as follows: Coremaking, Machine Molding, Dry Sand and Green Sand Molding, Cupola Practice, Foundry Rigging, Mixing Iron, Foundry Materials, Shop Calculations, Coke, Oil, and Electric Furnace Operations, Metallurgy, Shop Economics, Foundry Layouts, etc. Fortunately, we have within our own foundry organization men who possess the necessary mechanical and metallurgical qualifications to teach the above-mentioned subjects.

Summary

We frequently hear foundry managers exclaim: "What's the matter with the American boy? You cannot get one of them near a foundry." Let me assure you that there is nothing the matter with the American boy. All he needs is encouragement, a square deal and good wages to get him into the foundry and keep him there. But no redblooded American boy in this age will let you exploit him by making him do laborer's work. The time has passed when he will let you put him on the business end of a 200-pound "bull" ladle and carry iron half a block. The American boy of today takes considerable pride in his personal appearance. When

he arrives at the shop in the morning he wants a place to hang his clothing. He does not want to hang good clothes on a rusty spike driven into a dirty brick wall. When his day's work is finished he wants a clean, dry place to change his working clothes before going out in zero weather. Neither does he care to be saluted with a growl and an oath by a half-drunk muddle headed understrapper who may have been chosen for his job of "herder" more on account of his pugilistic ability than his knowledge of foundry practice.

There are hundreds of foundries in this country today operating, or attempting to operate, under conditions as described above. Quite often some of these foundries fail. Knowing the conditions, we do not wonder why. Sometimes you will hear a foundry owner say: "A boy in a foundry is not worth a nickel the first year of his apprenticeship." A statement like that is the purest kind of unadulterated "bunk," and though there may be a very few exceptions, the man who makes such an assertion is not able to get the right perspective, and old time foundrymen who are familiar with the true situation will not let such a remark go unchallenged. If you cannot make any money from a boy's efforts in his first year of training, do not blame it on the boy, as the chances are you need a new foundry superintendent or foreman. The foundry today surely offers a greater opportunity for advancement than any part of an industrial plant because the field is not as crowded as many of the other trades.

Conclusion

One thing is certain: We must make every effort possible to reinstate the American boy in our foundries. When he comes to work in the morning greet him with a smile instead of a frown. Get acquainted with him. It will pay you big dividends in the end. Don't throw him into the melting pot and forget all about him. Before you put him on any kind of foundry work be sure that he is properly warned of any danger connected with it. Many times we have seen splendid young fellows mutilated because they were not warned of the hazards of some task assigned them. The American boy is your very best bet and is 100 per cent all right if you give him a square deal. A million of them gave

a splendid account of themselves in France as you well remember, and we are sure they can render just as good an accounting in the foundry industry if you give them a chance.

With a constant lessening of the visible supply of competent molders facing the foundry industry, mechanical appliances and attachments will have to be installed in our foundries to eliminate the hard manual labor incidental to the work in order to make the job attractive. We did it for the foreigner. Let us do something for the American boy.

Research Laboratory—American Steel Foundries

By W. C. Hamilton,* Indiana Harbor, Ind.

During the World War the American Steel Foundries operated a forge plant on their property at East Chicago, Ind., and the buildings have been dismantled with the exception of the power house, a part of which has been remodeled to take care of a research laboratory. This building, on account of its rigid construction and general dimensions, has proven an ideal one for the purpose. The massive foundations allow for the operation of very delicate equipment without the usual annoyances from vibrations. It is 36 feet wide and 320 feet in length, only one-half of the length being occupied by the Research Laboratory.

The laboratory is divided into several departments. The work room covers a space 36′ by 80′, the chemical laboratory a space 20′ by 40′ with a balance room 12′ by 20′, and the metallographic room a space 9′ by 19′. In addition, there is a dark room, a library and two large offices, together with wash rooms.

Equipment Installed

The following equipment has been installed:

Ajax High Frequency Induction Furnace.

Stewart Industrial Gas Furnace with Automatic Control.

*Research Director, American Steel Foundries.

Two Leeds and Northrup Hump Furnaces with Automatic Control.

Combination Rockwell Dilatometer and Coefficient of Expansion Furnace.

Leeds and Northrup Critical Temperature Instrument.

R. R. Moore Endurance Testing Machine.

Riehle Bros. Izod Impact Testing Machine.

Riehle Bros. Tensile Machine, 100,000 lbs. capacity.

Scleroscope.

Olsen Brinell Hardness Testing Machine.

Rockwell Hardness Testing Machine.

Two Amsler Wear Testing Machines.

Leitz Metallographic Outfit (with lenses good for a visual magnification up to 2,500 diameters and a photographic magnification up to 10,000 diameters. There is also a special lens for macrostructures from normal size to a magnification of eight diameters).

Polishing equipment for Microscopic Work.

The machine shop is equipped to take care of the work necessary in the preparation of the different test specimens. A number of photographs are presented to show certain equipment and its arrangement.

The library is being gradually furnished with the latest technical books and in addition there are the proceedings of various technical societies together with the issues of several industrial magazines of interest. A complete set of the publications of the Bureau of Standards is considered a very valuable asset to the library.

High Frequency Induction Furnace

The Ajax high frequency induction furnace has proven an ideal one in which to make small heats of ferrous alloys. Recently an article in an English paper described a method of making steel by radio in a wooden box which was a reference to a high frequency induction furnace.

A motor-generator set furnishes single phase power at 960 cycles and 900 volts. This voltage is impressed on a water-cooled copper coil of about 50 turns which acts as the primary circuit of a coreless transformer. A crucible containing the charge to be melted is placed within this coil. Any electrically conductive material charged in the crucible acts as a short-circuited secondary of the transformer and absorbs the inductive energy of the primary coil, converting it to heat energy. The normally low power factor of such an inductive load is corrected by a bank of static condensers. It would be entirely practical to have the coil

FIG. 1—GENERAL VIEW OF THE PHYSICAL TESTING ROOM

and crucible surrounded by a wooden box. The similarity to radio is only because a high frequency induction current is used.

Crucibles made of graphite, magnesia and silica are practical, but for the melting of various alloys of steel, the silica crucibles have proven most satisfactory. Between the silica crucibles and the coil carrying the current, there is packed ordinary silica sand.

These silica crucibles nearly always develop cracks which are almost immediately sealed by the slag, and the steel with a higher surface tension has never been known to penetrate through. Moreover, the crucibles are fluxed away making the walls very thin at places, but the sand back of these spots fuses together making a very effective patch as good as the original wall.

FIG. 2—GENERAL VIEW OF THE CHEMICAL LABORATORY

It is possible to make from 12 to 15 heats in a silica crucible before it is discarded, equivalent to about 1,000 pounds of metal. The crucibles cost $5.80 each, or $11.60 per ton of steel melted. Less than twenty-five minutes is required to make a 65-pound heat and one of 140 pounds can be made in less than one hour. The current used is approximately 40 kilowatt hours per 100 pounds of steel melted, equivalent to 800 kilowatt hours per ton. At a cost of 1.1 cent per kilowatt hour this current consumption is worth $8.80 per ton of steel melted.

With the renewal of crucibles when necessary this furnace is always ready for use. It is simple to run and there is no dirt connected with its operation. There is no contamination of the charge except by a fluxing of the silica from the crucibles and the temperature of the molten metal is under control by changing the

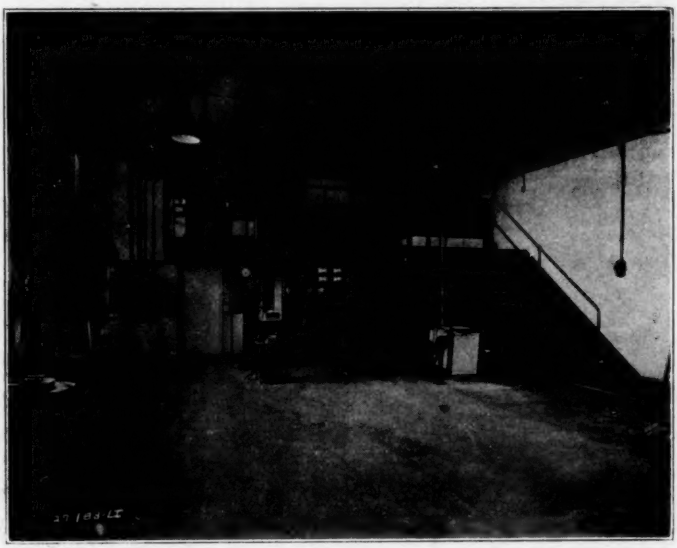

FIG. 3—VIEW OF INDUCTION FURNACES IN CENTER, WITH HEAT-TREATING FURNACES AT THE LEFT

current. Another very important factor is the agitation given the molten mass due to the induction current. This motion guarantees a thorough mixing of additions almost as soon as they are melted. In making ferrous alloys, the charge used is either boiler punchings or armco iron, depending on how low a sulphur and phosphorus content is desired. The steel melted is poured into sand molds designed to give test specimens. It is possible to obtain sections six inches in cubical size in order to study the

influence of mass on the subsequent heat treatments and resulting physical tests.

Heat Treatment of Tests

The heat treatment of the tests is carried out mostly in the Hump furnaces, although the gas furnace is used when temperatures over 2000 degrees Fahr. are desired. It is, of course, desirable to obtain the critical temperatures of the different compositions before the steel is heat treated.

The Leeds and Northrup instrument is very satisfactory in these critical temperature determinations, but there are certain

FIG. 4—THE R. R. MOORE ENDURANCE TESTING MACHINE

compositions which do not give a sharp Ac_3 point with our use of this instrument. A Rockwell dilatometer has proven a valuable help. This instrument is installed to be used either in connection with a small furnace heating tests 1" by 3" or in connection with one of the Hump furnaces heating large sections.

In the small furnace, it is expected that we will be able to obtain the coefficients of expansion but so far our work has been limited to the matter of obtaining the temperatures at which the steels start to contract in heating, which temperatures are the beginnings of the Ac_1 ranges. The end of this contraction, which is the last of the Ac_3 range, is of course noted. The same is done

in the expansion during cooling, and the total ranges of contraction in heating and expansion in cooling give the information of greatest value in Heat Treating.

In addition, the Hump furnaces give a break in the charts as the steel passes through the critical temperatures. The temperature of these breaks on the pyrometer charts indicate where the decalescence begins in heating and where the recalescence begins in cooling, and it is entirely practical to heat a bar of steel in the Hump furnaces without first obtaining the critical points and by watching the pyrometer chart know approximately when the heating is high enough for proper refinement.

The Hump furnaces are very well suited to the drawing of specimens, as they can be automatically controlled to any temperature up to 2000 degrees Fahr. Chromel-alumel couples are used in these furnaces. Automatic attachments have been added whereby either a bell is rung or the power is shut off after a certain period. By this arrangement, a long test may be stopped on the night turn with no supervision.

Machine Shop Equipment

The machine shop has the equipment necessary to prepare test specimens, starting with coupons or large castings. No machining is done by piece work as quality is the essential thing in test specimens representing research work.

The Heald grinder with a magnetic chuck to hold specimens is very useful in the preparation of parallel surfaces with a smooth finish to be used for Hardness testing and Macro Examinations.

Endurance Machine

The R. R. Moore endurance machine has not been employed to obtain the endurance limit of steels. This investigation requires too long a series of tests to be practical using only one endurance machine. So far the endurance tests have been made with a load of 55,000 pounds per square inch, this load being above the endurance limit of the steels tested but below the elastic limits. In this way a test is made in from one to ten hours, depending on the number of revolutions necessary for fracture.

Pull Test

The pull tests are made on standard two inch bars, the stress strain diagrams being obtained by the autographic attachment and their interpretation is made by the Johnson method.

In addition quick tests on bars maintained at high temperatures are being made with a measurement of the extension and permanent set for different loads.

Wear Test

The wear testing with the Amsler machines presented many problems before satisfactory results were obtained.

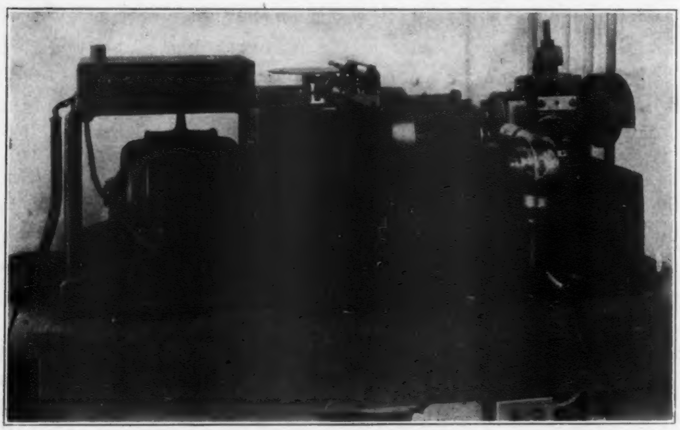

FIG. 5—AMSLER WEAR TESTING MACHINE

Specimens 1¾-inch in diameter with a width up to ⅜-inch are used. One specimen revolves at a speed 10 per cent less than the other when the diameters of the two specimens are the same, so that a slippage between the specimens is maintained. In our work so far, one specimen has been made of a definite composition at a definite hardness, this hardness being greater than the hardness of any of the specimens under investigation. The hard

standard is run at the faster speed and as the specimen, under test, wears away, the reduced diameter results in a greater difference in the peripheral speeds of the two specimens. This arrangement of course exaggerates the wearing conditions of a metal that does not resist wear. In other words, a specimen that starts to wear rather decidedly with a 10 per cent slippage will wear more rapidly as this slippage increases, due to the wearing and therefore reduction in diameter.

In addition to the slippage an adjustable lateral motion is given to the specimens as desired and it is also possible to give a bumping action to the specimens. There is also an attachment whereby the friction between the two specimens may be measured. This attachment is especially important when bearing metals or lubricants are under investigation.

The machines as delivered are equipped with a spring attachment whereby the load is applied to discs 1¾ inches in diameter revolving against each other in opposite directions and running at a speed of approximately 10,000 revolutions per hour. As the specimens wore, the tension on the spring became less and therefore the load could not be maintained constant. A floating load hanging on springs has been substituted with very good results.

However, the most annoying obstacle has been the formation of iron oxide on the wearing surfaces, especially when the tests are over 45 Rockwell-"C." The oxide acts as a lubricant, preventing natural wear. Fans were installed to cool the specimens and the blast of air removes much of the metal as it is worn into a powder. Nevertheless there is a skin heating due to the friction and a formation of iron oxide with which to contend.

When the wearing action is rapid the worn metal and oxide do not adhere to the specimen. In this case the worn particles are of a flaky nature and are blown away by the fan. On the other hand, when the wear is very slight the few particles formed are of microscopic size and hence are more readily changed to iron oxide which forms as a glaze on the specimen.

The Bureau of Standards has reported this difficulty and

has used a strip of copper pressed against both the specimens to remove this glaze of iron oxide, with more or less success. In our work we have avoided placing any material against our specimen under test but have used both copper and spring steel in contact with the standard. In every case the prevention of the oxide glaze on the standard insures no glaze on the softer speci-

FIG. 6—IZOD IMPACT TESTING MACHINE

men being tested. The spring steel has been found more efficient than the copper, but whatever is used must make perfect contact with the periphery of the standard specimen. It is more practical, however, to increase the load as the resistance to wear increases so that an appreciable wear is obtained; thereby preventing the polishing of the specimen.

The load and number of revolutions in use were decided

upon after a number of preliminary tests under different conditions. The load per square inch is not known, as we do not know the area of contact between the two discs. It was found that certain loads distorted the metal too severely and we finally decided on a load of 50 kilograms and 50,000 revolutions for specimens up to a hardness of Rockwell-"C" 45. The specimens weigh 65 grams and the above test results in a loss of 4 grams or 6 per cent as a maximum, the time required being slightly less than five hours. Greater loads are, of course, necessary under certain conditions. Attachments have been made whereby the machines are automatically stopped after the desired number of revolutions have been made.

Wearing properties of steel are being investigated in reference to composition, microstructure, and hardness obtained by different methods of heat treating.

Metallographic Work

The metallographic work being done on steel may be divided into three classes:

First.—Photomicrographs from normal size to a magnification of eight diameters. This work deals with the casting structures in connection with dendrites and imperfections visible to the naked eye.

Second.—Photomicrographs at a magnification of 100 diameters. This work covers the detection of inclusions and microscopic defects and also the general structure of the steel.

Third.—Photomicrographs at a magnification of 1,000 diameters. This work covers the identification of the impurities and constituents present and this statement may well be modified to an attempt at these identifications.

In this attempt a magnification higher than 1,000

diameters is very often necessary. It is felt that a good method for the identification of impurities is lacking, and on account of the complex nature of these impurities it seems that the chemist and metallographist must work hand in hand.

In order to interpret the constituents of steel and their relative forms, it is too often necessary to inquire what treatment had been given the steel under examination. What gives to steel the property to harden is still a much discussed question and it has been predicted that the X-Ray will some day solve the problem.

However much can be learned by a study of steel at high magnifications under the microscope and in our research laboratory this study is receiving much attention.

Chemical Laboratory

The chemical laboratory was built sufficiently large to take care of work of various natures, but so far the work has been mostly analytical.

The work undertaken up to the present may be outlined as follows:

1. Production of Alloy Steels
2. Chemical Analysis
3. Heat Treatment
4. Machine Work
5. Physical Testing
6. Metallographic Examination

In addition, steel in various forms has been sent in from our different works to be examined.

Personnel

The equipment necessary for the above work has been placed in charge of different men, mainly to insure its proper maintenance. The organization is small, consisting of four technical men, a stenographer, two machinists and a janitor; it is therefore

not satisfactory to limit one man's activity to any one department. At least two technical men are familiar with any piece of equipment and it is our desire to have all the technical men prepared to perform any test.

In addition to the author, the technical men and their respective universities are: Assistant Research Director, C. E. Sims, University of Illinois; E. H. Burkart, Massachusetts Institute of Technology; G. A. Lilliequist, University of Berne, Switzerland.

Objectives

The prime object of the research laboratory is to obtain facts concerning steel for castings and its heat treatment. The work so far has demonstrated very emphatically the necessity of such a procedure. At the present time there is no indication of a dull period in this department.

Research is nothing new. In "The Story of Philosophy," by Durant, it is brought out that the first example in European history of research on a large scale was under the direction of Aristotle, who was born in 384 B. C. It is related that a fund equal to $4,000,000 was turned over to Aristotle by Alexander for research work in the sciences.

Two thousand years later, Sir Francis Bacon in writing of himself, states, "I possessed a passion for research, a power of suspending judgment with patience, of meditating with pleasure, of assenting with caution, of correcting false impressions with readiness, and of arranging my thoughts with scrupulous pains. I had no hankering after novelty, no blind admiration for antiquity. Imposture in every shape I utterly detested. For all these reasons, I considered that my nature and disposition had, as it were, a kind of kinship and connection with truth."

From present indications, it would seem that the business

man of today is thinking as did Sir Francis Bacon when the above was written in 1577, and with his backing no one can predict what truths may be brought to light through research.

General Characteristics of Alloy Steel Castings

By J. W. Frank,* Chicago, Illinois

Alloy steel castings are the answer to the demands of the engineer and the manufacturer for steels of improved quality and strength. By the proper application of alloying elements to steel, we are able to obtain increased physical properties, such as tensile strength, elastic limit, reduction of area, resistance to impact, resistance to abrasion and resistance to oxidation, that could not be obtained from the best of carbon steel castings. The great strength of alloy steels is being utilized in reducing the size and weight of integral parts, thereby eliminating much of the bulk and weight of the final assemblies, with the added advantage of more uniformity.

As it is imperative that the steel casting industry keep pace with the demands made upon it, we have all seen the tendency for the steel foundryman to advertise extensively, steels with fancy names or even numbers, steels with varying contents of carbon and manganese, which cannot be compared to the real alloy steels, which carry, in addition, nickel, chromium, vanadium and molybdenum.

*Chief Metallurgist, Chicago Steel Foundry Co.

Each of the alloy steels has its own definite characteristics. Due to the increased service, these steels are able to demand a better price than is asked for ordinary steel castings. By their use, machinery that has multiplied its work power to many times its limit previously set, has been developed.

Three Classes of Alloy Steels

The characteristics of alloy steels are many and varied. Nevertheless, there are three distinct classes, and their lines of demarcation are clearly marked. First are the steels of high physical properties, such as tensile strength, ductility, resistance to impact, abrasion, distortion and fatigue. The second classification deals with steels with extraordinary properties, such as resistance to corrosion and magnetic permeability.

The third classification deals with the heat resisting alloys. While these alloys are not, in the sense of the word, alloy steels, their growing application in the make-up of heat treating appliances grants them a place and consideration in this article.

Manganese Steel

The first of the alloy steels, both in conception and in application, were the manganese steels. Those of low alloy content, from 1 to 1½ per cent manganese have not been classified as alloy steels until recently. In the days when the Bessemer process was in general use, certain foundrymen, at first by accident, and later by design, permitted the manganese content to rise to this figure, with excellent results. These castings were considered as nothing more than a good grade of converter steel. Of late, this steel has been heralded as a new alloy steel, and enormous quantities of it have been sold under many and various trade names. Manganese steel of this analysis, when properly heat treated, has excellent tensile strength and ductility, with very good resistance to abrasion. It has been extensively cast into caterpillar shoes, truck wheels, and in fact, anything that requires higher physical properties at a minimum of expense. The low cost of this alloy steel is its chief asset and it can in no way compare with others such as nickel-chrome steel.

Manganese steel of 12 to 14 per cent content is known uni-

versally and has its application clearly defined. It stands alone in respect to hardness and resistance to impact wear. Due to its extreme hardness, it cannot be machined, and must be ground into shape. Where machining cannot be eliminated, soft steel inserts must be used, being either pressed or cast into the larger castings. Manganese steel also undergoes a plastic flow or deformation, therefore its use is not recommended where wear is due to abrasion. Castings for ball mills, pulverizing machinery and rock crusher jaws illustrate the uses of this high manganese steel.

Alloy steels containing nickel or molybdenum, with manganese somewhat higher than normal, deserve to have a wider acquaintance among manufacturers of steel castings. Manganese has been called the Cinderella of the alloying elements, receiving no credit, and often bearing the brunt of the work.

Nickel-manganese steel usually contains nickel in the neighborhood of 1 per cent, with 1 to 1½ per cent manganese. The usual carbon range is .30 to .40. The use of the nickel obviously adds to its cost, but the increase in ductility and toughness, amply justify it. This metal also has a higher Brinell hardness, than the straight manganese steel of low content, under similar heat treatments. It is cast into substantially the same class of work as the 1 to 1½ per cent manganese steel.

In the manganese-molybdenum steels, the manganese is kept within the same limits, with molybdenum .20 to .40. The results, as a whole, are the same as with nickel-manganese steel, except that the elastic ratio is raised somewhat.

Nickel Steels

Nickel steels are the best known and the oldest of all commercial alloy steels. They were developed primarily for use in armor plate and ordnance, but since the war, and the stoppage of naval competition, their peacetime usage has been increased enormously. The nickel range is from ½ to 5 per cent, with carbon .10 to .60. Its characteristics are a high tensile strength and elastic limit, with very good ductility, fine grained structure, and usually, freedom from blow holes and porosity. These steels are used where extreme toughness is the outstanding requirement. The lower carbon members of this series are invaluable for parts that

are to be case hardened. Their use results in a very tough core, with a hard case, which is the ideal condition. Bridge castings, rail clamps and car replacers are a few of the numerous uses to which straight nickel steel can be put.

The alloys of high nickel content, the magnetic alloys, are hardly of much use to the foundryman, at least, at present. They have abnormal magnetic constants—permeability, permanence and the like. This metal is now made only into bar stock for the electrical industry, but could be cast into motor or dynamo frames, and probably will be some day.

Nickel-Chrome Steels

The nickel-chrome series are a large and comprehensive list. They are very well known, and the most widely used of all the alloy steels now on the market. Nickel and chromium complement each other, and form an ideal combination, having unusually high strength, very good ductility, and a remarkable resistance to fatigue and abrasive wear. The analysis ranges from ½ to 3½ per cent nickel and from .45 to 1.75 chrome, with carbon from .10 to .60. The ideal condition is where the ratio of the nickel to the chrome is in the vicinity of 2 or 2½ to 1. As is true with straight nickel steels, the members of this series having low carbon contents, find application in castings that are subsequently carburized, and as a general rule, are more or less interchangeable with them, but giving a somewhat heavier and harder case. The medium carbon steels have the widest application and the greatest possibilities. Where abrasive wear is encountered, they are supreme. They are used extensively for caterpillar shoes, chain belt, rolling mill rolls, excavating buckets lips and teeth, oil well machinery, hoisting drums, brake drums, special trackwork, lightweight car wheels, in fact for anything where wear is due to abrasion and not to impact. Brinell hardness is valueless as an index to this resistance, but actual service tests have proven, time and time again, that, in this respect these steels are superior to others that are much harder. Evidently Brinell hardness has no connection whatever with abrasive resistance. Toughness can be obtained by increasing the alloy content and allowing the car-

bon to drop to about .30. This metal is very useful for high pressure valves and fittings and for railroad knuckles.

High Nickel-Chrome Heat Resisting Steel

The high nickel-chrome steels, strictly speaking, should not be classified as alloy steels, being really ferrous alloys. The iron is seldom over 60 per cent and may be as low as 20 per cent. This is really an academic distinction, however, and many steel foundries are making castings of this material at present. The ranges of the alloying elements are extremely wide, nickel varying from 20 to 65 per cent, chrome from 7½ per cent to as high as 40 per cent. The silicon may be either normal or anything up to 5 per cent.

So much has been claimed for analysis, in the service of these castings, that a word or two about their manufacture would not be amiss. We all know that if our carbon steel castings are not solid, are porous or are scabby, their period of usefulness will be shortened, and it is reasonable to suppose that the same would be true of heat resisting alloys. A good casting of medium alloy content may be equal or even superior to the most expensive composition poorly handled in the foundry.

Recent tests have demonstrated that pots of greatly varying alloy contents, show life entirely disproportionate to the composition. On microscopic examination, it developed that some were thoroughly deoxidized while some were not. The lengths of service were absolutely in line with the degree of deoxidation. This condition could be due to faulty melting practice, regardless of whether alloy scrap was used or not, or to bad sand conditions. The manufacturer with many years' experience in making good steel castings behind him, obviously has the advantage here. Therefore it would not be an extravagant claim that analysis only be evaluated 25 per cent for the length of service, good foundry practice being responsible for the other 75 per cent.

The carbon is in some cases as low as .20 but in the alloys of high nickel analysis, often goes up to over 1.00. In the alloys of medium content, if the carbon is allowed to be over .50 to .60, trouble can be expected from cracking as the castings are very hard and brittle. The function of silicon and small percentages

of aluminum in heat resisting metals has just lately been recognized. Some pots and boxes are even being made in plain 3 per cent silicon steel, although I am not familiar with the results obtained.

The heat resisting steels, if properly made, are tough, somewhat difficult to machine, and show excellent tensile strengths from room temperature to about 1750 degrees Fahr. There is a gradual loss in strength, but it is not by any means as rapid as is the case with other metals.

Tensile strength is of no use in design, however, as less of a stress is necessary to cause a rupture, if it is sustained. The outstanding feature of these alloys, as their name would indicate, is their remarkable resistance to oxidation. Failures are seldom due to oxidation as often they show no trace of scale after almost indefinite length of service. If care is taken in not overloading them and in not heating or cooling them too rapidly their life will be greatly prolonged. The resistance to oxidation of this metal is best illustrated by the fact that it is impossible to cut it with the oxy-acetylene torch which brings them to an intense heat and then exposes them to a stream of pure oxygen. Heat resisting alloys are cast into annealing pots, carburizing boxes, lead pots, branding irons, oil burners, and heat treating furnace parts, such as linings, chain belts, racks, and similar parts for furnaces used in vitreous enameling. A rather high price differential is paid for such castings, but they prove very economical when heat hours are taken into consideration. In this field especially, intensive advertising is carried on, and without exception, all alloys are marketed under trade names.

Chrome Steels

Straight chrome steels of low content have been cast but their use is uncommon. Chromium, by itself, gives more hardness than carbon, and at the expense of less ductility. The chromium is usually from .60 to 1.50 per cent with carbon usually from .15 to over 1.00. These steels, especially those containing the more carbon, are used where rigidity and freedom from dis-

tortion are the predominating requirements.

The high chrome steels are the stainless steels and irons. The minimum chromium content is 12 per cent, but some contain as much as 40 per cent. The members of this series that have the lowest carbon are the so-called stainless irons, but they are all made by the same processes, so are really steels. They do not require any heat treatment to bring out the stainless properties, while the stainless steels do. The carbon is seldom over .60 in any event.

Oil refineries have been heavy buyers of castings of this material, lately, for equipment used in the cracking of the crude petroleum oils, which have a corrosive action at high temperatures due to a high sulphur content. Castings have also been made for food handling machinery, both to keep the food products free from contamination, and to increase the life of the equipment. As ordinary steel castings have a very limited period of usefulness in the handling of acids and caustic alkalis, chemical industries have been using increasing quantities in the form of agitator arms, kettles, pipe lines, driers and other parts. The irons have the maximum resistance to corrosion, but are only moderately hard. The stainless steels are also said to take and retain a better polish.

Molybdenum Steels

Nickel and nickel-chrome steels were so enthusiastically received by industry in general, that investigators were encouraged to study other elements as potential alloys. The most successful of these are the molybdenum and vanadium steels and combinations with elements mentioned previously.

Straight molybdenum steel is not common in castings at present. The molybdenum is usually .20 to .40 but may be as high as .80. The main advantage in using this metal is the relative ease in welding them to other parts in fabricating.

Molybdenum in conjunction with chromium produces a steel, the use of which is increasing by leaps and bounds. The uncertainty of results that has been troublesome in the past, has been entirely eliminated with improved methods of adding the molyb-

denum. The outstanding effect of the molybdenum is the unusually high elastic ratio, with high tensile strength and good ductility. The advantage of this steel over chrome-nickel is the ease with which it can be machined. In actual practice it has been shown that, at the same Brinell hardness, a considerable saving can be made in the average time of each machine shop operation. The drawing temperatures of this steel are unusually high and it is less susceptible to overheating. Molybdenum is almost always kept within .20 to .40 and chrome .70 to 1.10. Carbon is usually .20 to 1.00 for the general run of work. Steel of this analysis is especially tough and has been used with success in blooming mill rolls. If the carbon is allowed to rise above this figure to almost 2.00 the rolls are extremely hard and rigid, and have excellent resistance to abrasion.

The addition of molybdenum to a nickel-chrome steel results in a metal that should be of particular interest to foundrymen. It retains all of the good qualities of the nickel and the chrome, the ease of machining of the chrome-molybdenum steel, and, in addition, has the peculiar characteristic of hardening almost as hard by air quenching as if a liquid medium were used. It is the solution, in large castings, or castings, the nature of which makes water or even oil quenching precarious. Distortion can be kept at a minimum, internal strains lessened, fire cracks eliminated, and the cost of the heat treatment appreciably lowered. Quite a bit of the finish can be pared off the patterns, thus saving additional time and expense in machining. This makes nickel-chrome molybdenum steel the ideal metal for cast die blocks. These are steadily displacing forgings, due to the heavy expense of sinking the die into a solid block. They can also be resunk very cheaply, as they can be remachined without annealing. With low carbon, at or nearly .30 and higher nickel and chrome, a steel of very high ductility and elastic limit is obtained. It is highly recommended for high pressure fittings, for railroad knuckles, and whereever great dynamic strength is necessary.

Chrome-Vanadium Steels

Castings of chrome-vanadium steel have been made for some time but have never come into general use. Vanadium steel speci-

fications are always "minimum .15, .18 desired," chrome .80 to 1.10. It also has high tensile strength and good ductility, but its characteristic is its resistance to fatigue. Since the steam locomotive has had its power and weight increased, many frames and other massive parts have been made in alloy steels. Chrome-vanadium steel has been most common in these castings.

Care in Manufacture of Alloy Steels

Alloy steel castings, in general, require more care in manufacture, than do castings of plain carbon steel. As cast they are hard and brittle, and unless properly annealed, are apt to remain so. In general, the cast structure is harder to break up, and at the same time it is most essential that this be done. They require a longer annealing at a higher temperature, as a rule. Care must be taken, if surface welding is necessary that such parts be re-annealed, as otherwise hard spots are sure to be found on machining.

The real benefits of the alloy additions are not brought out unless the castings undergo a heat treatment. A simple air quench from annealing temperature, followed by a draw at a comparatively high temperature, often accomplishes wonders, as compared to the results obtained by a straight anneal.

Alloy steels cannot be considered a panacea for all the troubles that arise in the use of steel castings. Neither must the user place the blame for isolated poor results, on the contained alloys. The user must use the same discrimination in judging results, that he uses in his judgment of ordinary steel castings, as well as other products. He must not let results of the products of second rate manufacturers of steel castings blind him to the results that can be obtained with a first class alloy steel casting.

Alloy steels have come to stay. The steel foundryman must

be constantly on the alert to improve quality, and to take advantage of improvements when they arise, so that he will be able to get his share of this large and constantly increasing class of business.

Manganese Steel

By H. P. Evans* and A. F. Burtt*, Chicago, Ill.

Introduction

Perhaps the first mention of non-magnetic iron-manganese alloys is by Rinman, who in 1774 observed that the white brittle metal obtained by fusing equal parts of gray pig iron and manganese oxide was not attracted by a magnet. About 1830 David Mushet prepared alloys containing up to 30 per cent manganese, using manganese oxide, iron oxide, cast iron, charcoal and a fluxing agent. He noted the non-magnetic nature of the metal but apparently the carbon content was too high to give the properties later obtained by Hadfield. Considerable investigations of manganese additions were carried out by German producers and more especially the Terre Noiri works in France about 1875. The reports of these investigations tended to show that steels containing much over 1.00 per cent manganese were brittle. The reports included an alloy of 11 per cent manganese content, but the carbon content was 2.42 per cent and the steel was brittle.

Historical

In the face of these and many other discouraging reports concerning manganese alloys Robert A. Hadfield in 1883 finally produced the alloy known throughout the world by his name—

*Metallurgist and Assistant Foundry Superintendent, respectively, of the Pettibone Mulliken Co.

Hadfield steel or more commonly called manganese steel. This alloy has the following analysis:

Carbon	1.00— 1.45%
Manganese	10.00—14.50%
Silicon	0.30— 1.00%
Sulphur	0.01— 0.03%
Phosphorus	0.04— 0.10%

The ratio of the carbon and manganese contents is maintained at approximately 1 to 10. Hadfield published an exhaustive report in the Journal of the Iron and Steel Institute of Great Britain in 1888. Hadfield first used the converter for the manufacture of manganese steel. He melted low phosphorus low sulphur pig iron in a cupola and then blew it dead in a converter. Molten ferro-manganese, melted either in a special cupola or crucible was then added to bring the heat to the proper analysis.

One of the chief difficulties encountered in this process was the inability to use old heads, gates, and other manganese scrap without the attendant loss of manganese due to oxidation during melting. Air furnaces were used to a certain extent, but many hundreds of tons of manganese scrap were piled away awaiting the discovery of a method of retaining the manganese content of the scrap. Advantage was taken of the so-called Swedish practice of blowing converter metal, whereby a portion of the heat developed during the blow is obtained from the manganese in the metal, thus utilizing the manganese content by using it as a source of heat. Improvement in cupola practice of melting ferro-manganese by the use of a low blast, low coke ratio, etc., cut down the loss of manganese in the melting of ferro-manganese. With all the improvements available, however, there was a considerable loss of manganese during melting, and not until after the advent of the electric furnace was it possible to make manganese steel using manganese scrap without a considerable loss in the manganese content.

The manufacture of manganese steel by the open-hearth process was handicapped by the fact that it is impossible to refine a charge containing manganese steel scrap without the loss of

most of the manganese due to oxidation. Hence all manganese steel made in the open-hearth has been made by ladle additions of ferro-manganese. While it is possible to make excellent manganese steel by ladle additions of ferro-manganese, and many tons of open-hearth manganese steel have given satisfactory service in industry, the inherent difficulties of this method and the opportunities for obtaining a non-uniform product are perfectly evident.

The first electric furnace melting practice used for manganese steel was similar to that used for carbon steel. A basic bottom was used because the basic manganese slag attacks an acid lining. Soft steel scrap was melted under an oxidizing slag and the slag removed. A second slag was added and the heat finished under reducing conditions exactly as for carbon steel. Finally the required amount of ferro-manganese was added, the bath brought to the proper temperature and tapped. Soon it was found that the ferro-manganese could be added immediately after slagging off, the subsequent practice remaining unchanged. A little later the ferro-manganese was added immediately after the heat was melted and then the heat was finished under a single slag. Later full advantage was taken of the neutral atmosphere of the furnace during the melt-down and the reducing action of the carbide slag permitting the melting of ferro-manganese and manganese scrap from a cold charge and finishing under a single carbide slag.

Basic Electric Melting Practice

While it is possible in a general way to describe the present-day practice of melting manganese steel in a basic bottom electric furnace, there are specific conditions arising peculiar to manganese steel that necessitate very careful operation and the employment of a very responsible melter well acquainted with the peculiarities of manganese steel. Low carbon low phosphorus steel scrap, manganese steel scrap and sufficient ferro-manganese to bring the manganese content of the bath when melted almost to the specifications are charged cold into the furnace. The manganese steel scrap may range from none to practically 100 per cent of the charge. Power is turned on, using high voltage for melt-down in order to shorten the time of this operation. Since gases are being

given off constantly from the burning of the electrodes there is at all times a pressure of gas out through the door and tap hole. Practically no air enters the furnace and any oxidation results almost entirely from the rust and oxides of the charge. It is due to this fact and to the presence of a carbide slag during the finish of the melt that manganese scrap and ferro-manganese can be added with the initial charge in the electric furnace without the loss of manganese that occurs in the converter and open-hearth furnace. When the charge is melted the bath is stirred and a laboratory test is taken. Ferro-silicon is added, and lime, fluor-

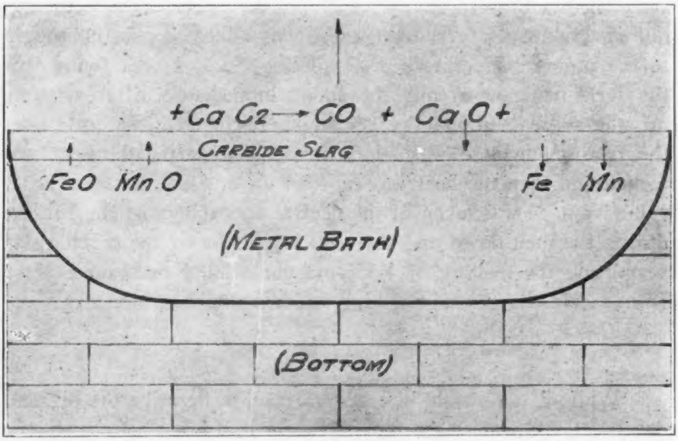

FIG. 1—DIAGRAM SHOWING DEOXIDIZING REACTION

spar and coke added to form a slag. The furnace is operated under a lower voltage in order to protect the refractories, and the refining operation begins. Necessary additions as indicated by the laboratory analysis are then made. If it is desired to raise the manganese without raising carbon, silico-manganese or low carbon ferro-manganese are added. The bath is stirred vigorously and proper additions are made to form a carbide slag.

Deoxidation

Calcium carbide is a very strong deoxidizing agent. Deoxidation is accomplished as shown by the following reaction and as illustrated in Fig. 1.

$$Ca\ C_2 + 2\ FeO \rightarrow CaO + CO + 2\ Fe$$
$$Ca\ C_2 + 2\ MnO \rightarrow CaO + CO + 2\ Mn$$

Since the CO is formed at the contact of the slag and bath, and not in the body of the metal, it is not absorbed and dissolved by the bath to an appreciable extent. The iron and manganese go back into the bath and the CaO into the slag. Fig. 1 represents the metal bath in the electric furnace with a covering of carbide slag and illustrates the above reactions. The carbide first reduces the easily reducible oxides of the slag. It then attacks the oxides dissolved in the bath. Due to the surging action of the bath and occasional stirring these oxides are removed from the bath and the metal from the oxide returned to the bath and deoxidation is complete.

Desulphurization

Calcium carbide is probably the most efficient desulphurizing agent known. Desulphurization is accomplished by the following reaction:

$$2\,CaO + CaC_2 + 3\left(\begin{matrix}MnS\\FeS\end{matrix}\right) \rightarrow 3\,CaS + 2\,CO + 3\left(\begin{matrix}Mn\\Fe\end{matrix}\right)$$

Since sulphur is naturally removed by manganese under a basic slag this additional removal brings the sulphur content down to almost a negligible point and sulphur ceases to be a problem.

Degasification

The ferro-silicon acts as a degasifying agent as follows:

$$2\ CO + Si \rightarrow SiO_2 + 2\ C$$

Ferro-silicon additions should be made early enough during the finish of the heat that time is given for the resulting silicon dioxide to separate from the bath.

Pouring Practice

The teapot ladle seems the most satisfactory type of ladle for

manganese steel, though the tap ladle and lip ladle are used satisfactorily to some extent. Care must be exercised in controlling the pouring temperature of the metal. If poured too hot excessive shrinkage and a cutting action in the mold most pronounced at the gated end is apt to occur. Large heads, gates and risers permit the pouring of the heavy jobs on the cold side. Light work is poured of hotter metal.

Manganese steel is not adapted for the wide range of analysis used in carbon steel. Different types of castings, however, do require somewhat different analysis. In general, heavy work, especially of irregular section, is poured from metal of less than 1.25 per cent carbon in order to obviate the liability of cracking during cooling. In some work where hardness is essential even with the sacrifice of some ductility the carbon may be raised to 1.40 per cent.

The shrinkage of manganese steel is considerably greater than that of carbon steel, so all patterns must be made accordingly. The shrinkage of carbon steel is not over 1/4 inch per foot, while that of manganese steel is approximately 5/16 inch per foot. Because of this fact, and other factors peculiar to manganese steel, many unsatisfactory and weakened castings are turned out of foundries not thoroughly familiar with manganese steel through daily contact with it on the floor.

By the proper use of chills in the mold at the junction of two different thicknesses of metal, rates of cooling of the two sections can be controlled and cracking eliminated. After the castings are cooled sufficiently they are shaken out.

All railroad castings are relieved as soon as they are set. The gates and heads are dug out, bars bent and copes raised so that the castings may cool lying free in the drag.

Particularly difficult castings subject to undue stresses while cooling are shaken out hot and immediately placed in the annealing furnace and annealed without being allowed to become cool. Heads and gates which are broken off are removed before heat treating because they are too tough to be broken after the heat treatment. The larger heads and gates are burned off.

Heat Treatment

Heavy castings annealed in a car type furnace are brought to a temperature of 1600 degrees Fahr. and allowed to soak at this lower temperature in order to obviate the excessive oxidation that would occur by soaking at the quenching temperature. They are then brought to a temperature of from 1850 degrees to 1925 degrees Fahr. and quenched in water. Smaller castings treated

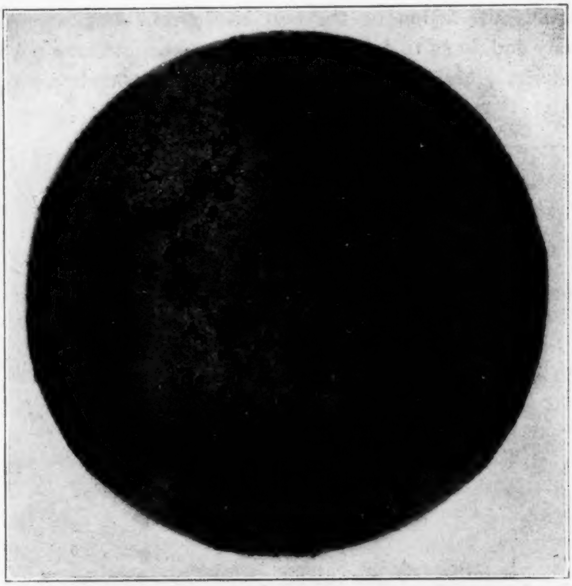

FIG. 2—MANGANESE STEEL AS CAST; OF AUSTENITIC STRUCTURE WITH CARBIDE SEGREGATION ALONG GRAIN BOUNDARIES OF THE AUSTENITE GRAINS AND SCATTERED THROUGHOUT THE GRAIN ITSELF

in a suitable furnace are quenched in water from the same temperature. After a sand blast the castings are ground to the proper finish and straightened, if necessary. The grinding department is a very important part of a manganese steel foundry. Since the castings are too tough to be machined commercially, all finishing

is done by grinding and elaborate grinding equipment is necessary to obtain the finish and close tolerances demanded by the customer. Soft steel inserts are cast in parts where machining or drilling is necessary.

Properties of Manganese Steel

Manganese steel is comparatively soft, registering a Brinell number of 150 to 200 and yet possesses a peculiar toughness that withstands the action of the best tool steel. It possesses the elasticity and ductility of soft steel and at the same time possesses the extremely high tensile strength of 100,000 pounds per square

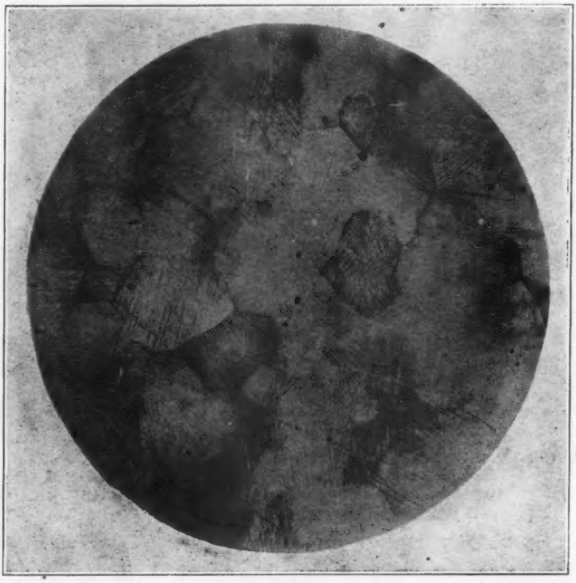

FIG. 3—WHEN PROPERLY ANNEALED AND QUENCHED, THE CARBIDE SEGREGATIONS OF FIG. 2 ARE DISSOLVED INTO THE AUSTENITE AT HIGH TEMPERATURES AND DUE TO THE OBSTRUCTIVE ACTION OF HIGH MANGANESE CONTENT ARE RETAINED IN SOLUTION BY THE DRASTIC QUENCH IN WATER

inch, which enables it to withstand the severe shocks under which ordinary steels fail completely.

The following are the physical properties of properly heat treated cast manganese steel:

Tensile strength	80,000 to 140,000 lbs. per sq. in.
Elastic limit	30,000 to 55,000 lbs. per sq. in.
Elongation	25% to 35%
Reduction of area	20% to 35%
Brinell hardness	170 to 200
Scleroscope hardness	40 to 50

Because of a peculiar slipping along its planes of cleavage when under heavy stress manganese steel does not have a definite

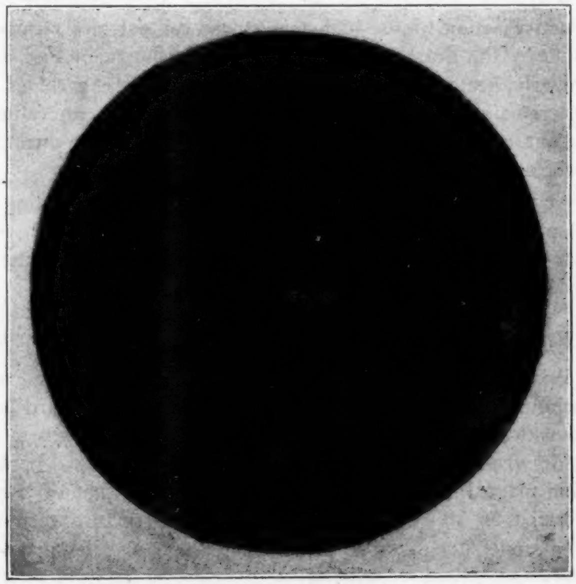

FIG. 4—IF IMPROPERLY HEATED OR QUENCHED, PORTIONS OF THE CARBIDE SEGREGATIONS OF FIG. 2 MAY EITHER REMAIN UNDISSOLVED BECAUSE OF INSUFFICIENT ANNEALING OR COME OUT OF SOLUTION AGAIN BECAUSE OF SLOW COOLING DURING THE QUENCH

yield point and this figure cannot be obtained by the drop of the beam. For the same reason the elastic limit is hard to obtain. A ½ inch square cast bar after heat treatment should bend 180 degrees around a pin of its own diameter.

The shearing strength is very high—much higher than one would expect from the elastic limit. This is caused by the hardening during cold deformation mentioned later.

Structure of Manganese Steel

Manganese steel as cast has an austenitic structure with carbides segregated along the grain boundaries of the austenite grains and scattered throughout the grain itself, as shown in Fig. 2.

When properly annealed and quenched these carbides are dissolved into the austenite at the high temperature and, due to the obstructive action of the high manganese content, are retained in solution by the drastic quench in water, as shown in Fig. 3. If improperly heated or quenched, portions of these carbides may either remain undissolved because of insufficient annealing or come out of solution again because of slow cooling during the quench, as shown in Fig. 4.

At times the stresses set up in the metal while cooling may develop slip planes in the austenite grains. In Fig. 5 these are shown as hair lines running along the cleavage planes of the separate Austenite grains.

Peculiar Changes Caused by Tempering and Cold Work

When manganese steel is given a drawback after water quenching it loses its toughness and changes to a hard brittle martensitic or cementitic structure. When it is given a sufficient drawback to reach a Brinell number of 450 it will possess a specific magnetism approximately 40 per cent of that of Swedish iron rated at 100 per cent. The lancelike structure seen when viewed under the microscope, and the high specific magnetism identify the structure definitely as martensitic at least to a considerable degree.

When subjected to severe stresses such as compression, tension, or repeated blows, manganese steel tends to slip along its planes of cleavage and develops a hard structure which in extreme

cases reaches a Brinell hardness of 500. When the Brinell hardness is raised to 450 by cold work the resulting specific magnetism is less than 5 per cent of that of Swedish iron, and the resulting structure when viewed under the microscope differs from the original austenitic structure only in that it shows very definite slip planes. The identity of this latter structure is a much mooted question among metallographic authorities.

The superior wear resisting properties of manganese steel are due to a considerable extent to the hardening action that takes place when the casting surface is subjected to shock. As the surface is slowly worn away the newly exposed surface has been

FIG. 5—AT TIMES THE STRESSES SET UP IN THE METAL WHILE COOLING MAY DEVELOP SLIP PLANES IN THE AUSTENITE GRAINS. THESE SLIP PLANES ARE SHOWN AS HAIR LINES RUNNING ALONG CLEAVAGE PLANES OF THE SEPARATE AUSTENITE GRAINS

hardened by the previous shock and thus there is throughout the life of the wearing part a tough body of metal with an extremely wear resistant surface at all times exposed to the abrasive material. At times a casting subjected to extremely heavy shock and seemingly the worst possible type of service may wear even better, due to this extreme increase in hardness, than a casting receiving a purely abrasive wear and no shock.

Uses of Manganese Steel

Manganese steel castings stand in a class by themselves for use in many wear resisting and shock absorbing parts. A few of the specific uses are as follows:

Railroad work:—Frogs, switches, crossings, guard rails, etc.

Crusher parts:—Liner plates for ball and rod mills, mantles for gyratory crushers, hammers for hammer mills, jaw plates, and roll shells.

Other miscellaneous parts:—Dippers and dipper teeth, tractor shoes, chain, sand suckers and pumps, conveyors, chutes, gears, sheaves, etc.

A Modern Plant for the Heat Treatment of Miscellaneous Steel Castings

By A. W. Lorenz,* South Milwaukee, Wis.

This paper describes a modern plant, uniquely equipped for the full quenching and tempering of miscellaneous steel castings. With this plant an output of over five hundred tons per month may be obtained, at a cost of about one-half cent per pound. It is hoped that the paper may be of interest, in that it points out the possibilities of producing maximum quality castings at a comparatively small cost.

It has been found that when certain types of alloy steel castings are subjected to quenching treatments, their physical properties may be improved from fifty to one hundred per cent. Of one grade of steel, the following comparison is typical:

Treatment	Yield Point	Ultimate Strength	Per Cent Elongation	Reduction of Area, Per Cent
	—pounds per sq. inch—			
Normalized	82820	115030	19.0	37.3
Quenched	157870	167910	12.2	40.0

When such results can be obtained at a relatively small increase over the cost of casting, the subject of heat treatment becomes a lively issue, suggesting many applications which would otherwise be prohibitive.

The Bucyrus-Erie Company's experience with heat treated castings extends over a period of eighteen years, and at the

*Metallurgist, Bucyrus-Erie Co.

present time approximately one-third of our entire foundry output is fully quenched and tempered. This processing is entirely separate from that of annealing, which is conducted in the foundry proper, and which is given to all castings, regardless of subsequent treatment. In order to handle the special treatments, plans were drawn up in 1926 for a new shop which would represent the most modern developments in efficiency of operation and ability to produce a high-grade product, and at the same time be capable of handling eventually from one thousand to fifteen hundred tons per month of quenched and tempered castings. The first unit, with a capacity of five hundred tons per month, was finished in September, 1927. This unit embraces several distinctly novel features in the handling of castings for treatment, and it is believed that a description of these features will prove of greater interest than the more or less hackneyed details of furnace construction and fuel economy common to all heat-treating installations.

Building

The building in which this installation is housed is 65 feet by 80 feet, of brick and steel sash construction, extremely well lighted and ventilated, in sharp contrast to the old idea that heat treating shops should be clothed in darkness. The floor is concrete throughout. A good broom constitutes part of the regular equipment, and the floor is cleaned at regular intervals. The cleanliness of the shop, even in periods of maximum production, has been remarked by all who enter the plant. These conditions have a stimulating effect on the operators, and encourage careful workmanship.

Adjacent to the main building is a side bay, 35 feet wide, in which the sub-station is housed. This sub-station furnishes power also to an electric melting furnace in the steel foundry, and for general power purposes.

Directly in line with the heat-treating department, and one hundred and sixty feet distant, is a building at present used for foundry purposes, one hundred and twenty feet long. The design and construction of these two buildings are identical, so that with

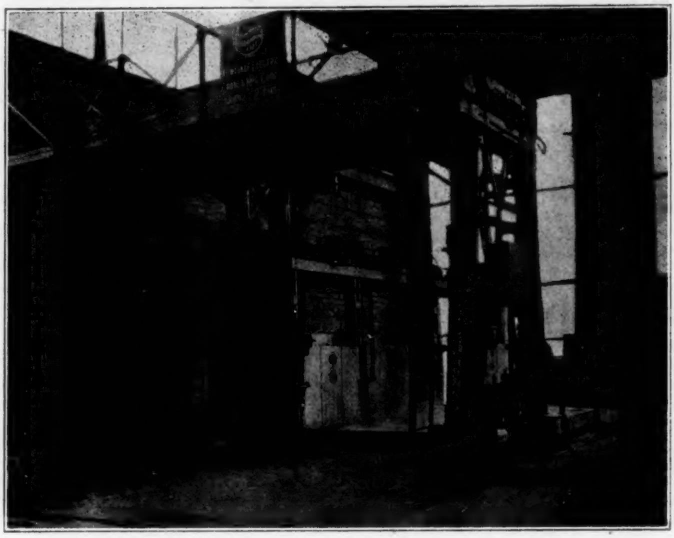

FIG. 1—CHARGING MACHINE, WITH LIFTING CARRIAGE IN POSITION TO ENTER STATIONARY LOADING RACK

the intervening space already noted, provision is had for practically unlimited expansion.

Furnaces and Equipment

The heating equipment is unusually simple, consisting of four box-type electric furnaces with hearths 5 feet by 6½ feet, and one single-chamber car-type electric furnace, with car 3 feet by 14 feet. With a large-scale production in mind, our first leaning was naturally toward some type of automatic or semi-automatic continuous furnace, but while such furnaces may be of advantage on selected or special work, none could be found which would handle all types and sizes with equal facility. With castings ranging from five to two thousand pounds in weight, the difficulty of automatic or continuous operation will be appreciated. Decision finally narrowed down to simple box and car-type furnaces, because of their flexibility.

FIG. 2—PRONGS ENTERED BETWEEN RAILS OF UNLOADING RACK, READY TO LIFT CHARGE

The car-type furnace is of conventional design, with heating elements on the side walls only. Due to the narrow width of the furnace, bottom heat was considered unnecessary.

Auxiliary Equipment and Mode of Operation

The shop is served by one five-ton traveling crane, one gasoline tructractor, and one charging machine of special design. It is the method of charging the box furnaces by means of this charging machine which constitutes the most radical feature of the installation.

Reference to the photographs, of Figs. 1 to 6, shows that the machine is essentially a one-leg gantry or traveling crane, equipped with a set of six forks or prongs suspended from an overhead trolley in such a manner that the prongs may be moved up or down, in or out, at the will of the operator. The whole machine travels up and down the shop on suitable rails set in the floor and on the side wall of the building.

FIG. 3—CHARGE ON PRONGS, ENTERING QUENCHING FURNACE

While the choice of electricity was largely dictated by an extremely low power rate in the Milwaukee district, it should also be noted that this type of heat presents several distinct advantages which peculiarly adapt it to heat-treating operations:

(1) Extreme uniformity of heat application.

(2) Extreme closeness of temperature control.

(3) Impossibility of unduly "forcing" a heat.

All of these factors are important in securing a uniformly high-grade product. Regulation, of course, is entirely automatic, by means of a well known type of pyrometer-controller sensitive to five degrees plus or minus. The box furnaces are of the twin-chamber type. Heating elements are nichrome ribbon, located under the hearth and on the roof. The hearth itself is formed of alloy castings, in the shape of an inverted T, providing not merely a hearth, but also a series of rails, eight inches high on eight inch centers.

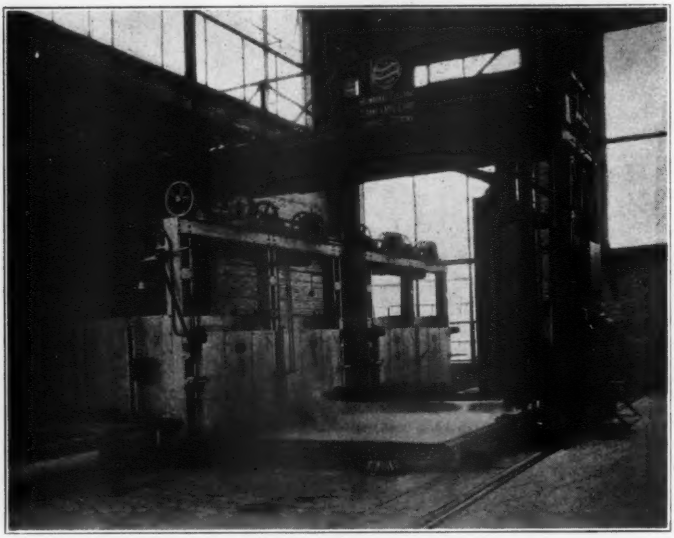

FIG. 4—CHARGE WITHDRAWN, READY TO SUBMERGE FOR QUENCH

Again referring to the photographs of Figs. 1 and 2, it will be observed that an elevated platform extends along the side of the building, in alignment with the four box furnaces. This platform is used for the loading and discharging of materials in and out of the furnaces. The platform is twenty inches high, permitting material to be unloaded from trucks or trays with a minimum of effort.

Set in this platform are two loading racks, which are exact counterparts of the furnace hearths, in that they consist of a set of rails, eight inches high, spaced on eight inch centers. The top of each rack is flush with the surface of the platform.

Immediately in front of the quenching furnaces will be seen a quenching tank, 17 feet by 12 feet by 5 feet deep, with a working capacity of 6,500 gallons. This tank is filled with water, maintained at a constant temperature of 125 to 150 degrees Fahr.

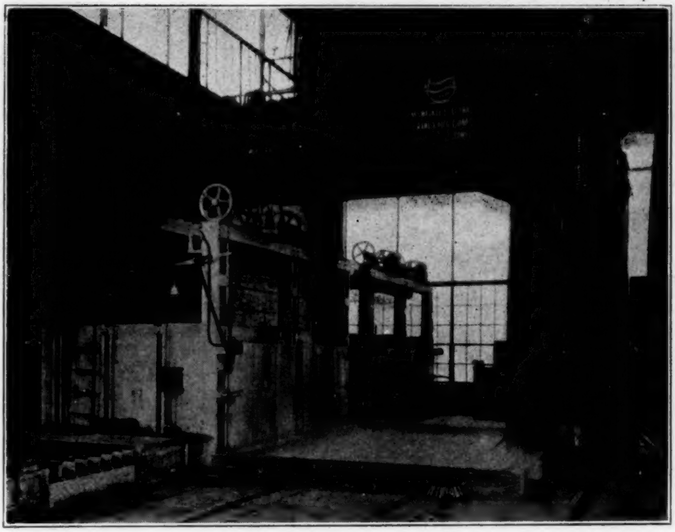

FIG. 5—PRONGS SUBMERGED, QUENCHING THE CHARGE

To accomplish this control, the tank is equipped with inlets for cold water and steam. It is also connected by means of a circulating system with a cooling tower located on the outside of the building.

In operation, material is delivered by truck or by crane to the loading platform, where two helpers arrange the pieces upon one of the loading racks. Pieces over sixteen inches in widest dimension, and some pieces as small as eight inches, will rest on the rails without further support. Smaller castings are placed upon perforated trays. The fork of the charging machine is then moved forward and entered between the rails of the loading rack, beneath the charge (Fig. 2). When fully entered, the prong carriage is raised, thereby lifting the whole charge off the loading rack. The charge is then transferred to one of the quenching furnaces, where by a reversal of the previous operations, it is deposited on the furnace rails. The charges usually range from

FIG. 6—CHARGE ENTERING DRAW FURNACE. DOOR CONTROL POSTS VISIBLE IN RIGHT FOREGROUND

one thousand to four thousand pounds in weight, and the transfer is effected in from thirty seconds to one minute. Quenching is performed in like manner, but since the quenching tank is directly in front of the furnaces, the heated charge is transferred from the furnace to the tank in from five to ten seconds. After the quench, the charge (still suspended on the charging fork) is transferred to a second furnace for tempering.

The entire cycle, including the opening of the doors, is handled by one man on the platform of the charging machine. The furnace doors are controlled by push buttons set on posts within convenient reach of the charging machine operator. Limiting devices, stops, and indicators, permit perfect alignment of forks before opening the doors, protecting the furnaces from damage, and speeding up the transfer with minimum loss of heat.

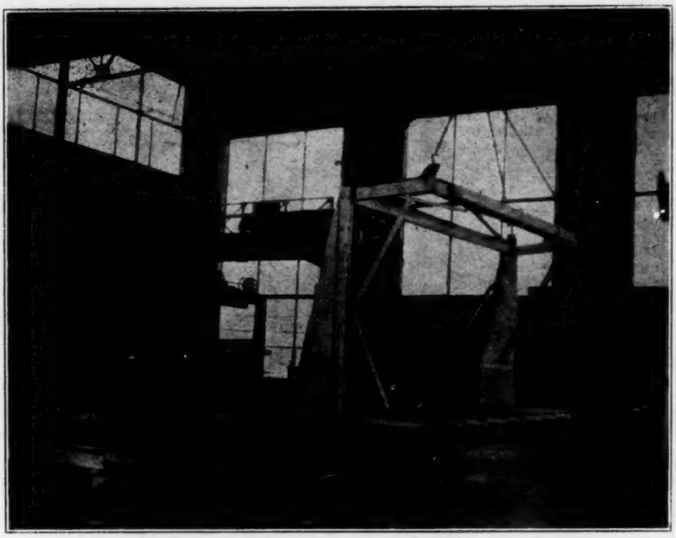

FIG. 7—SUSPENDED CHARGING RACK, USED IN LOADING AND UNLOADING CAR-BOTTOM FURNACE. LOADING TABLE SHOWN AT REAR LEFT, WITH CHARGE READY TO TRANSFER TO FURNACE

It is interesting to observe that notwithstanding the economy of this arrangement, such economy has been obtained without the least sacrifice in quality of the product. In fact, the method has several advantages. Pieces are never piled promiscuously, but are neatly and uniformly placed, always in the same position. The quenching is not a mere dumping proposition, but each piece is fully exposed on all sides to the quenching medium. The whole scheme promotes a uniformity in heating and quenching seldom obtained in heavy pieces, except with automatic quenching devices.

Car-Bottom Furnace

With the general trend of steel foundries, so far as electric annealers are concerned, toward twin or even three-chamber types, it may be interesting to observe that in the present installation, the car-bottom furnace consists of only one chamber and one car. Such an installation is not adapted for furnace-cooling treatments.

FIG. 8—SUSPENDED RACK TRANSFERRING CHARGE FROM LOADING TABLE (AT LEFT) TO FURNACE CAR AT THE RIGHT

It is intended entirely for the heating of special air-hardening steels, and also for shafts and similar pieces for quenching.

It is well established that furnace or slow cooling is decidedly inferior to air-cooling for development of maximum strength, and it was not considered the function of this plan to equip for such a treatment. Nevertheless, the method of operating this furnace tends to produce normalized or quenched and tempered castings at a cost not appreciably greater than that of simple annealing in twin chamber car type furnaces.

Reference to photograph, Fig. 7, will show a carefully balanced lifter, which again employs the prong idea, and is suspended from the overhead traveling crane. A rack made up of 12 inch "I" beams will also be observed, on which rests a suitable furnace charge. The beams are placed on 18 inch centers, similar to the spacing of rails on the furnace car. With this apparently unwieldy, but really quite simple device, a car may be unloaded,

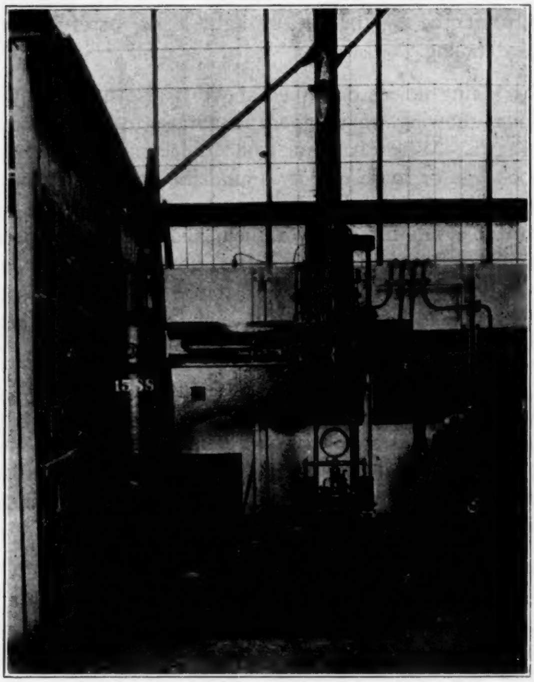

FIG. 9—BRINELL HEAD MOUNTED ON RADIAL DRILL ARM

reloaded, and shoved back in the furnace, in five minutes time, thus increasing efficiency not merely by continuous utilization of the heating chamber, but also by reclaiming a large portion of the heat stored up within the car itself. With twin car types, the heat absorbed by the car is largely lost. Naturally, there is also a saving in maintenance and depreciation costs with the simpler equipment.

The removal of the heated parts to a separate rack for cooling is distinctly beneficial where air-cooling is desired, since the cooling rate is considerably more rapid and uniform than could be obtained on a hot car. The racks being entirely open underneath,

permit free access of air. Maximum hardening conditions are further promoted by the use of light loads, carefully arranged for rapid cooling.

The lifting device described above is also used in quenching operations, showing up to good advantage in the quenching of heavy shafts. When handling such objects, common procedure is to hook one or more chains around the shaft (or around bars supporting the shaft as it rests on a hot car), which is quite an uncomfortable job for the workmen, and not always performed with facility. By means of the lifter, however, the workmen are always stationed at a comfortable distance from the car, there are no adjustments to be made, and the whole charge may be picked up at one time and transferred to the quenching tank without delay.

The entire routine incidental to the above plant for a monthly output of 500 tons is handled by three men on day turn, including the foreman, and two men on night turn. One of the day crew devotes 25 per cent of his time to Brinell inspection and takes care of the clerical duties.

The checking of Brinell hardness on treated work is a routine procedure, and to facilitate the testing of heavy pieces, the Brinell head has been mounted on the arm of an old radial drill machine, as shown in photograph, Fig. 9. Castings are placed on the drill table, and the Brinell apparatus swung into position above the point to be tested.

In conclusion, it is hoped that this paper will emphasize the rapid strides now being made in the heat treatment of steel castings, and promote a further interest in same. Foundrymen cannot be indifferent to the heat treatment of their product. If they are to withstand the inroads of other branches of the iron and steel industry, they must be prepared to take advantage of every development leading to a better material.

Materials Handling and Its Relationship to Building Plans

By E. F. Scott,* Cleveland, O.

In presenting a paper of this title the writer is necessarily placing before you a rather abstract subject in that it is practically impossible to formulate a rule of layout that will answer the varying conditions of foundry plant development. Each kind of foundry, gray iron, steel, malleable, non-ferrous—offers a number of different solutions even in a typical way. When gray iron foundries alone are considered for the production of their various items it is readily seen that a multitude of layouts is possible. Considering further the other types from tonnage and production standpoints we would have a further number of possibilities. This paper can, therefore, only speak generally on this subject of relation of building layout to material handling equipment.

It is realized that much that is here stated is obvious and apparent and reiterative. This fact, even though true, nevertheless, need not cause us to lose interest in this subject for it is only by bringing constantly to the attention of foundry executives these points that finally better and more efficient foundries are built and cause the industry to proceed on its way to greater development. The foundry executive is too little inclined to study seriously the layout of his new plant or the revision possible to his present factory. Details are irksome, they involve a too studied procedure

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for him to do other than to pass them on to others. He is too much concerned with the result and not the means to accomplish results.

One of the very necessary points to consider when developing a new foundry layout or the present layout change is the relationship of building plans to material handling equipment. One might well say that this involves the sum and substance of foundry plant layout. It is true the production units, melting and cleaning units, must be properly placed but the material handling is not only integral for each department but also binds the whole plant together to form one production system, so that it is by far more responsible for proper building layout than mere location of the above units.

We all know that many tons of raw and semi-finished material must be handled to produce a ton of finished castings. This fact alone means that the modern foundry organization must study the material handling phase quite carefully, and this study in turn determines or helps to determine in a large measure the length, width and height of the foundry buildings. The building must be made as economical as possible. More area than needed requires more outlay of capital. Higher buildings require more appropriation of money. Heavy type buildings used where unnecessary only serve to make the profits that much more difficult to secure. On the other hand insufficient areas curtail possible production. Too low a building not only harms the project from a lighting and ventilating point of view but likewise renders impossible easy installation of sand handling equipment, or the like, or future installation of the same unless at increased cost.

Equipment Considered

The material handling equipment commonly considered might be listed as all cranes—overhead, locomotive, jib, hand or any other type; elevators, ramps with which winch and cables are used; charging machines; industrial track systems; hot metal carriers; monorails with trolleys as used for various purposes; conveyors as roller, drag type, car type, etc., for conveying molds, etc.; belt conveyors, and elevators for sand; buggies; cars; power trucks; overhead chain conveyors for castings. The placing of these equipments in buildings cannot help but render it absolutely

necessary that the definite relationship of them to the building be well established in order to secure at least somewhat near the ideal layout. It is a dangerous procedure to say without adequate investigation that you want so many square feet of area for a foundry plant and that you want it so long, so wide and so high. You might happen to be right but the odds are against you. Even the simplest foundry demands studied attention to proper layout and, needless to say, the more involved foundry requires extraordinary study.

Yard Equipment

First of all to be considered is the yard layout. It is here that production really starts in the receipt and proper assembly of all raw materials. Coke, pig, scrap, alloys, sand, limestone, core making material, all enter the plant generally in carload shipments, or at least in cars that must be unloaded and the material then placed in proper storage. If the foundry is so situated that no railroad siding enters the plant then truck shipments are necessary, and even so, proper storage is required. Likewise, the small foundry must arrange for a storage that is more than a few days' supply. The small foundry in most cases cannot afford the expenditure of much costly labor saving equipment. For that reason unless it is making something very special, as metal of a certain specification, it is bound in time to feel the effects of extreme competition. The small jobbing foundry will endure for some time but only because overhead is practically eliminated and profit is not considered in the usual sense but is absorbed as a wage or salary paid to owner or partners.

The foundry which passes the stage of being small must install some equipment to cut labor costs. Just where this line is drawn is difficult to formulate, because not only tonnage is a factor but likewise kind and number of castings.

Considering the yard equipment, the most commonly thought of material handling machine is the overhead electric crane. This requires a runway on which to operate and in this way there is a direct relation to building layout. The crane uses the clam-shell bucket, tub, or container of some sort, magnet, etc., to aid in the

unloading and placing of raw materials. This method cuts down the cost of handling considerably, if the tonnages handled are sufficient to pay for the machine, that is, if the cost of operation plus depreciation, interest, etc., is under the amount of wages paid out to unload the same kind and amount of raw materials.

In laying out a yard crane runway it is important to remember some details. In the first place the height of rail above the yard level or railroad track rail level must be determined. To merely determine a certain height from what someone else has used or from standard lift of some crane may get one into difficulty. The bucket used is one determining point. The operating headroom required plus the bin height, clearance above and distance of hook to rail, is one set of distances to consider. If the electrically operated bucket is used this cuts down height as a rule, but, on the other hand, the bucket is more costly. When a charging floor is served by the yard crane its height, plus rail or barrier around it, clearance for magnet and load, plus distance below hook required for a magnet and load and hook distance to rail are the total of dimensions. If coke is taken up to the charging floor by bucket or tub then this required distance must be considered. Charging floors vary so much that no distance can be established to suit every condition.

If material is not taken to the charging deck by the yard crane it may be possible to reduce the height of rail above yard or track level. However, in so doing, we must not overlook the railroad requirements for clearance above top of rail to underside of crane girder, usually about 20 to 22 feet. Fig. 1 shows a section through a yard, the relationship to the points above discussed being noted. These points serve to show that in even so simple a layout as a yard crane, we must be sure that the detail clearances, loads to be carried, placing of crane on runway so that cab will be on the proper side, position of conductor wires and so on, are all considered carefully.

The type of structure to use, that is, the vertical supports, girders and bracing are other points that are the concern of the structural engineer. He must design as economically as possible

in order that the cost of construction be kept as low as possible. Of course, the cost of crane, power wiring, etc., must be such as to make the total as low as possible. Only in this way can definite savings in labor be shown. The equipment installation must pay for itself or its installation is not warranted. If you cannot save labor it is an idle whim to want to install costly material handling equipment.

Care taken in the layout and design of such items as yard-crane runway mean an insurance against future changes which, to say little, are costly even when they do not involve much construction. It is needless to remark that plant layout should precede designing of foundries. Methods of handling, production, etc., should be determined as far as possible in advance so that building plans may be developed and carried on to completion

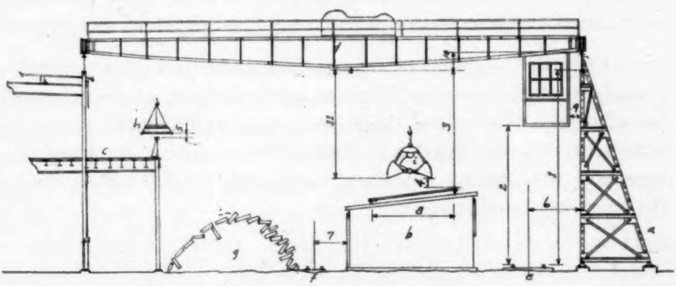

FIG. 1—a, CRANE "A" FRAME; b, SAND BIN; c, CHARGING FLOOR; d, OVERHEAD ELECTRIC TRAVELING CRANE; e, TRACK; f, INDUSTRIAL TRACK; g, PILE OF SCRAP IRON OR PIG IRON; h, MAGNET; i, CLAM SHELL BUCKET.

1, REQUIRED DISTANCE OF UNDERSIDE OF CRANE RUNWAY GIRDER TO TOP OF TRACK RAIL; 2, DISTANCE OF CAB ABOVE TOP OF TRACK RAIL—THIS MUST BE SUFFICIENT TO CLEAR A BOX CAR; 3, DISTANCE FROM HOOK TO TOP OF SAND BIN; 4, CLEARANCE OF BUCKET ABOVE TOP OF SAND BIN; 5, CLEARANCE OF MAGNET AND LOAD ABOVE TOP OF BIN WALL ON CHARGING FLOOR; 6, NECESSARY RAILROAD CLEARANCE REQUIRED FROM FACE OF "A" FRAME TO CENTER LINE OF TRACK; 7, CLEARANCE REQUIRED FROM CENTER LINE OF INDUSTRIAL TRACK TO FACE OF SAND BIN; 8, REQUIRED OPENING FOR HATCH IN SAND BIN; 9, CLEARANCE REQUIRED FOR CAB FROM FACE OF "A" FRAME; 10, DISTANCE OF HOOK BELOW TOP OF CRANE RUNWAY RAIL; 11, DISTANCE REQUIRED IN WHICH TO OPERATE CLAM SHELL BUCKET.

while the equipment is being specified and purchased. Where questions arise as what to make certain dimensions it is well to leave foundry layout to one whose experience has taught him the maximum and minimum of equipment clearances.

In the yard may also be placed other kinds of equipment. Locomotive cranes, skip hoists and conveyors may be used to handle materials and in locating and installing these we again will be required to investigate loads and clearances. Skip hoists are often used to take the coke up to a large bin easily reached from a charging floor or at the charging floor. Its supports become usually part of the building structure, hence we must know the loads to figure the structural members. The frame work will take up a certain amount of space so the exact details of this kind of a piece of equipment should be on hand before building plans are called finished. Conveyors when used as for sand, coke, etc., must also be located properly and in order that they may function efficiently must be laid out carefully in this regard.

Other yard equipment may include industrial track, portable unloaders, slag and waste disposal equipment, makeup-equipment for charges. Too often these seemingly unimportant pieces of equipment are neglected and then when a change is absolutely necessary the cost for installing same adds considerably more to the total for building cost.

Charging Equipment

The next part of a foundry development we may well consider is material handling relating to charging. In the gray-iron foundry the cupola still stands supreme as the melting unit, and to charge it there have been devised a number of different methods other than the old hand method. In this connection the delivery of material to the charging machine is also a necessary scheme to be laid out properly.

The cupola being once located in the best place for delivery of material, reception of raw materials, etc., it is then that the problem comes to charge it properly. If we use the old hand method, we, of course, must have room enough at the charging floor level for working purposes and also for such storage as we

desire to furnish. The elevator, ramp, hoist of some sort, or yard crane or locomotive crane, brings up the raw material to the charging floor. It is brought up in bulk or in made-up charges on cars and this makes it necessary that there be sufficient storage space for several charges ahead. Bulk storage requires bins so laid out as to receive the material easily and economically.

However, the tendency is at present to give considerable thought to mechanical charging. The methods of accomplishing this are numerous and vary from quite simple arrangements to those involving quite a complex system. The predominating idea is to place the made-up material into the cupola without further rehandling, thus eliminating a considerable labor item in most foundries. Some machines, as is well known, carry the bucket into the shell, others as a skip hoist, take the charge and discharge it into the cupola, the aim being to get the discharge point as near the center of the cupola as possible so as to cause the materials to spread as well as they can under such circumstances.

In any case the relationship of these various types of machines to the building must be surveyed thoughtfully. The decision as to whether to install a machine or not hinges on so many specific and local questions that again we cannot say you should install one or you should not. Tonnage handled enters into the question very strongly, but in two foundries of about the same capacity one may have low charging cost and the other one high charging cost due to perhaps certain unchangeable circumstances.

All factors must be considered logically and the dollar and cents saving carefully accounted for before it is well to take a fancy to this modern equipment and want to install it in your plant. It may almost certainly be said that in most modern large plants, of say 40 to 50 tons capacity upward, it will pay for itself. However, even so, the superintendent and metallurgist must be satisfied that the charging will produce results from their point of view. Saving labor in one place and losing castings or not securing metal as desired will not produce dividends at the end of the year.

But if the machine is installed, even though of simple design

as a hoist on a beam and a bucket that tilts into the cupola, we must be sure our loads and clearances are all thought of so that the building will be strong enough and there will be height, length and width enough in which to place the equipment.

Oftentimes, and it is good practice, the building is laid out and designed for future installation of charging machines. This is then placed as production increases. In this regard it is evident that ingenuity and judgment must be used, for though we may know what is being used at present, it is rather difficult to visualize just what the future will bring forth. However, it is practically safe to assert that if present loads and clearances will be sufficient no more than these will be required on future ma-

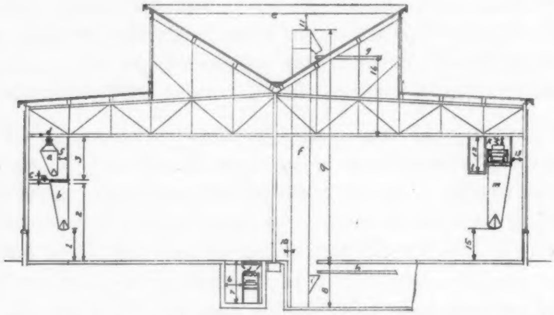

FIG. 2—a, CUPOLA; b, CHARGING MACHINE; c, BUCKET ON CHARGING MACHINE; d, HATCH IN CHARGING FLOOR THROUGH WHICH TO HOIST BUCKET.

1, REQUIRED DISTANCE FROM CHARGING FLOOR TO UNDERSIDE OF TRUSS IN WHICH TO PLACE CHARGING MACHINE, ETC.; 2, REQUIRED LIFT OR AMOUNT OF HOISTING DISTANCE FOR BUCKET; 3, REQUIRED HEIGHT OF BUCKET ABOVE CHARGING FLOOR TO CLEAR RAILING AROUND HATCH; 4, REQUIRED DISTANCE FROM CHARGING FLOOR TO UNDERSIDE OF CAB ON CHARGING MACHINE; 5, REQUIRED END DISTANCE OF CRANE BEAM FROM FACE OF BUILDING COLUMN; 6, REQUIRED DISTANCE OF EXTREME POINT ON CHARGING MACHINE TO FACE OF COLUMN; 7, CLEARANCE REQUIRED FOR CRANE BEAM FROM FACE OF CUPOLA.

In laying out a charging machine it is necessary that sufficient room be established from the far column to the cupola in order that the charging machine may operate efficiently, that is, in order that it may move to the center line of hatch and pick up its load from that point. This hatch should be placed at a sufficient distance to the rear of the cupola so that hoisting of charges will not interfere with the slagging off and dropping bottom.

chines of the same general type. Of course, a radical change in charging or melting will mean radical changes in equipment and layout.

Fig. 2 indicates a charging machine placed in a building. Usually the runways or beams for cranes or trolleys for these machines are not supported on structures by themselves. That may be the case in installations in old buildings. But in a new development, the building trusses and columns must be expected to be of sufficient strength to support the structure required. This eliminates expense and gives more area for the foundry layout.

For making up the charges in conjunction with the use of the charging machine, there are likewise certain relationships to establish between the building plans and material handling equipment.

Quite often the storages of pig, scrap, limestone, alloys and the like are in bins loaded by the yard crane. This yard crane also may place the materials in buckets which are then weighed and then taken up a hatch in the charging floor by the charging machine.

Another method places the material in bins and these feed into a weigh car or larry from which the bucket is lifted by the machine and then charged into the cupola. Other methods may also be used but in any case the design of the structures must definitely be determined by the layout of the particular handling equipment. This latter usually is placed in the yard under the crane runway and thus bears a direct relation to it as well as to the bins and building proper.

In other kinds of foundries as malleable, steel non-ferrous, the charging scheme may also be made mechanical. Cranes using buckets or trays perform similar operations to the cupola charging machine. In fact, the open hearth charging machine preceded the cupola charger. But regardless of how it is done the layout must be such as to clear sufficiently and the structure must support the loads properly. The matter of whether installation is warranted brings us back to a variety of conditions which must be determined first, we can then analyze the problem from the

investment standpoint purely in terms of labor saved. This means our building must not be elaborated upon too much but should be directly suited for the purpose.

Equipment Inside the Foundry

After charging equipment we may proceed to consider the equipment used in the interior of the foundry, yard and charging being thought of as perhaps exterior operations. The layout of material handling schemes inside the foundry determines the shape of the building in a large measure. While it is true consideration must be given to building costs in laying out the foundry, still if efficient labor saving devices are to function properly, the building must be built to house them. It is true that as concerns the building we can limit the size to the absolute minimum required for the layout of equipment. This is not always good practice, however, due to future changes that may be wanted and which cannot be foreseen just at present. In considering the modern foundry building it is not well to limit it to such a size that it will not lend itself to easy expansion and future incorporation of additional material handling equipment. Also, consideration must always be given to other factors, as light and ventilation.

Hot Metal Carrier: The first material handling that we should consider is the taking of the hot metal from the melting units to the mold or the bringing of the molds to some particular point for receiving hot metal, or perhaps some combination of the two methods. In the average jobbing foundry the overhead trolleys, running on monorails or tramrails, or the overhead crane perform a large part of the pouring. The monorail trolleys usually take care of the smaller and lighter molds.

For pouring the large molds the overhead crane takes the ladle from the cupola and carries it directly to the mold which has been made up on the floor directly underneath the crane. The lighter floors are served by smaller ladles and the hot metal transferred to smaller pouring ladles.

In pouring many floors of light molds many lines of monorail or tramrail are necessary to get the metal to each mold as it

lays on the floor. It must be handled quickly and efficiently. So many methods of accomplishing this are possible that descriptions of each would make this paper far too long. It is sufficient to say that enough operating room must be allowed each line of monorail and that these monorails and tramrails must be well supported and clearance allowed at columns and other points where obstructions might occur.

The hot metal carrier, ladle on trolley, or some sort of power machine as the man-trolley are often used on the monorail. These installations that involve the use of electricity or power require quite careful attention to clearances and loads before proper installation of them can be made. Aisles or gangways must be established for passage-ways and these kept clear for free passage of such equipment.

The considerations necessary for crane installation are about the same as in the case of a yard crane. There are a few more details that usually must be considered, such as end clearances of trucks, room above top of rail to bottom of truss, and the amount of lift the crane must have. Wheel loads, wheel base, extreme position of hook in relation to center line of rail, are other points also to be thought of. In considering the required height of rail above floor, the height of flasks on the floor must be computed in order to provide for proper clearance of a load being moved over them. Also when a flask must be rolled over it likewise must have sufficient clearance all around it so that no damage will be done to the mold during this operation. The current available and the wiring layout all must be thought of so that it will be installed properly. These points all give many things to think of besides mere structural and building details. They concern plant operation and in this way cannot help but make the foundry executive decide that building new foundries or revamping old ones is more than a mere architectural or structural problem.

Besides overhead systems, buggies or cars or trucks may be used for hot metal delivery. These need not concern us as far as loads on building steel or structure, but we must lay out gangways and tracks to accommodate them. Whether to pave gangways or

pouring areas with concrete or brick or use cast iron plates, all must be discussed. Concrete is cheaper than brick but spalls and cracks up sooner. Brick of the right kind as paving brick or hard burned brick of some sort is fine but costs more than concrete if laid on a concrete base as it should be. Plates are suitable but should be laid on a bed of concrete or well packed cinders and so this sort of a floor would be more costly than concrete. These plates laid without a good base soon become out of line with the others and make an unsuitable floor. Wood block burns too easily and so does other wood flooring.

For the molding floor proper concrete is well but it is rather hard on the men. Dirt floor is liable to be cold and damp unless well packed clay is used. Cinders also may be used in this way.

Handling Molds: After pouring the next step to consider is the handling of molds to the pouring stations to which hot metal is brought. Of course if no mold handling is done as in the usual jobbing floor type of foundry, the taking of metal to the mold constitutes the whole operation. The mold, if large, must be handled either by overhead crane or hand for shaking out. Conveyors of some sort are generally used to transport the molds to a pouring station. These are placed in such a manner along the molding machines as to receive the molds which are then carried around on the table of the conveyor. These conveyors may be of the roller type, chain drag, car-type. The building must be laid out to fully accommodate their requirements. Columns must avoid coming into their area in any such manner as to become obstructions to operation. Often trenches or pits are required in this connection and these must be large enough and must avoid column footings and projections.

Overhead mold conveying systems of the pendulum type or monorail or tramrail type, if attached or hung from the trusses, likewise add loads. If placed on independent structures sufficient space must be given them and suitable clearances around columns and any other vertical members must be kept.

Where molds are carried out from a molding machine for placing on a floor the overhead crane, often hand racked with

power hoist, is used. Sometimes lines of roller conveyor serve this purpose as well. These items of equipment must be considered in relation to the building, even though they seem insignificant.

Sand Handling: When sand handling systems are used as they must be, with the continuous molding system above noted, a study must be made of their relationship to the building plans. In connection with these systems the usual sand tempering equipment is used. This brings into the picture bucket elevators, screens, bins, tempering and revivifying machines, and so on. These demand certain types of structure which cannot be avoided and hence we must provide pent houses and high roofs. Also when sand distribution is considered we will require certain distances to the bottom cord of the truss in order to allow the belts or other conveyors to distribute to bins over molding machines or sand slingers, etc., in the right manner and so that the bins may be of the required capacity.

This sand handling method enters into the core room layout also in that sand properly mixed is distributed to the coremakers in like manner either on belts or conveyors or by trucks, buggies, or carriers on monorail or tramrail systems. This is done because some foundries demand a variety of core sand mixes which could not be distributed so conveniently, efficiently and economically by belt or scraper conveyor. Molding sand does not, as a rule, require so many mixes for the kind of casting being made as iron, steel, etc. In the case of core sand distribution above noted galleries are hung from trusses or supported off the columns. These are necessary for providing runways for trucks and must have proper layout. They affect the building structure by adding loads and construction details.

To return the shakeout sand to the tempering system, trenches or tunnels must be built, usually of reinforced concrete construction. These are so laid out as to include the return sand conveyors and require clearances and attention to detail.

Pits are also necessary to incorporate such equipment as elevators properly and these again mean we must be sure to make them of suitable structure and large enough and also waterproof them where conditions demand this. They ordinarily run into

some depth and hence must retain some considerable wedge of earth which requires structural attention. Figure 3 indicates a typical section combing many of the points above noted. Their relationship to the building is easily seen from this picture and from the notes in connection with it.

Shaking Out: Proceeding to the shaking out, knocking out of cores and cleaning, we find that the same kind of equipment—

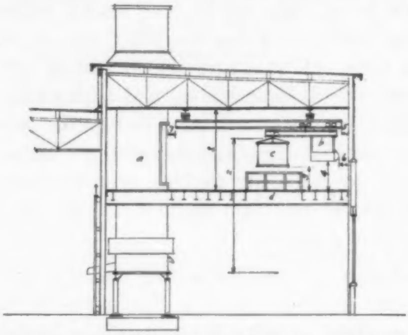

FIG. 3—a, SAND DISTRIBUTING BUCKET; b, HOPPER OVER MOLDING MACHINE FOR CORE BENCH; c, GALLERY; d, MONORAIL OR TRAMRAIL ON WHICH BUCKET OPERATES; e, HIGH ROOF REQUIRED OVER ELEVATORS; f, BUCKET ELEVATOR; g, SAND DISTRIBUTING CONVEYOR; h, RETURN SAND CONVEYOR; i, ELEVATOR BOOT; j, BELT CONVEYOR FOR REMOVING SHAKE OUT SAND; k, SCRAPER TYPE CONVEYOR FOR SAND DISTRIBUTION TO MOLDING MACHINES; l, WALKWAY ALONG CONVEYOR; m, HOPPER OVER MOLDING MACHINE.

1, DISTANCE OF GATE ON HOPPER ABOVE FLOOR SO THAT IT WILL DISCHARGE TO MOLDING MACHINE OR CORE BENCH; 2, HEIGHT OF GALLERY ABOVE FLOOR; 3, GALLERY DISTANCE BELOW BOTTOM CHORD OF TRUSS FOR PROPER HEAD ROOM; 4, CLEARANCE OF GATE ON BUCKET ABOVE FLOOR OF GALLERY; 5, SIDE CLEARANCE OF BUCKET FROM SUPPORTING STEEL; 6, CLEARANCE OF CONVEYOR SUPPORTS FROM SIDE WALL TO BE SUFFICIENT SO THAT A MAN CAN WORK CONVENIENTLY; 7, DISTANCE OF FLOOR OF TRENCH BELOW FOUNDRY FLOOR; 8, REQUIRED DISTANCE OF ELEVATOR BOOT PIT BELOW FOUNDRY FLOOR; 9, HEIGHT OF ELEVATOR ABOVE FOUNDRY FLOOR; 10, CLEARANCE AROUND ELEVATOR; 11, CLEARANCE OF HIGH ROOF ABOVE TOP OF ELEVATOR; 12, HEAD ROOM REQUIRED BELOW BOTTOM CHORD OF TRUSS FOR WALKWAY; 13, CLEARANCE FROM THE FACE OF COLUMN TO SUPPORTS FOR CONVEYOR; 14, CLEARANCE FOR FLIGHTS OF SCRAPER CONVEYOR BELOW BOTTOM CHORD OF TRUSS; 15, DISTANCE REQUIRED FROM GATE OF BIN ABOVE FLOOR TO INSURE PROPER INSTALLATION OF MOLDING MACHINE; 16, DISTANCE OF CONVEYOR ABOVE BOTTOM CHORD OF TRUSS.

cranes, monorails, trucks, etc., are used. They likewise demand all the above noted attention. Chain conveyors for taking the castings to the cleaning department or through a cooling operation also give points to consider from the building layout standpoint. Monorails or tramrails demand certain minimum radii for the trolleys or carriers used and where speed is necessary these must be increased. When power trucks are used turning radii and areas must be considered.

Handling Castings: The handling of castings after shaking out is no small item in foundry layout. The casting must be brought to the cleaning department quickly and with as little handling as possible. After cleaning there is likewise another handling to shipping room or other part of the plant. The detailed routing must be worked out carefully so that the building costs will not suffer. Changes in building construction are costly and the proper way to avoid them is to consider this part of the material handling as carefully as any other. Once columns are placed and trusses definitely located it is quite difficult to change them and even, if possible, it is extremely costly. These structural members are all important to the building, hence, it is the foundry engineer's responsibility to so determine them that the owner will not suffer or if they have been determined to so lay out his equipment to avoid changing them.

General: A well developed foundry from a material handling standpoint regardless of size or kind, gives us one with each department definitely connected. Each one is a unit tied together by one layout. The auxiliary equipment required as, for instance, to dispose of slag or waste, is likewise carefully embodied in the proper manner to save labor costs. Though each department may have different types or sections of buildings due to different demands of foundry operation, yet each building is considered carefully in its relation to material handling equipment. The foundry proper may require a high well ventilated section, while the cleaning room may be lower, but the layout on material handling equipment that binds the two together so reduces the areas required that we have building costs reduced to a minimum.

This last item is no small one in the new foundry develop-

ment. The more it may be reduced the less a foundry is taxed from a money making standpoint. Of course proper buildings are necessary and proper heating, lighting, ventilation, etc., all must be considered. Heating is an item to think of carefully in relation to material handling equipment in that layout of piping, unit heaters, etc., must avoid the items we have already mentioned. Buildings must likewise accommodate the production machine; they must be strong structurally and pass building codes and state code requirements; also they must have proper railroad or transportation facilities; and must be placed in such locations as to insure labor conditions that are suitable.

But even when all these necessary items are considered proper arrangement of the material handling equipment will serve to cut the buildings required to the lowest point possible. For instance, in any large combined foundry, if it is possible to combine the coremaking department into one unit it will mean a saving in operation. It is true different kinds of cores require different mixes of sand, binder, etc., and different baking, but if it is placed in one department and the finished cores transported to the various departments economically there is a saving over operating two or three different departments of the same general nature. In a small production type of foundry, space and equipment may be conserved by transporting made-up molds on monorail or tramrail to coring and shakeout stations. Many other examples might be noted wherein co-ordination of all possible kinds of one sort of operation into one unit with the proper sort of a material handling system will produce a foundry that will require less building layout than one where these careful considerations are not given.

The jobbing type of foundry still remains with us as one where it is believed that we cannot use material handling to any appreciable extent except possibly cut down the expenditure of human energy as much as possible, that is, taking the hard labor out of it by the use of cranes, hoists, and the like. It is true that this means some saving in the labor costs but it is felt that extensive use of conveyors for sand handling and mold conveying can-

not find their place here. The use of conveyors for continuous molding and pouring for sand handling systems has not been greatly developed for the jobbing foundry; however, as jobbing units become larger there is no reason why this type of foundry will not be able to be so laid out as to reduce as well areas required and make it a compact building.

Where changes of flasks are necessary a great part of the foundry must be used to store them, so as to have them convenient. This takes up production area and we are at once confronted with high building costs. A layout of some kind of material handling scheme that will allow the flasks to be placed in a less costly building but at the same time not impair the efficiency of foundry production will solve this sort of a problem.

Summary

To make a short resume it is desired to impress on foundrymen the extreme necessity of proper layout for material handling in relationship to building plans. This paper has endeavored to take one through the main equipment items required in the modern foundry and show how they involve the building. While every foundry is a problem unto itself, still the generalities herein indicated should serve to show that the new development of a foundry plant or rehabilitation of an old one demand that foundry engineering be used in its best developed and most available form. It is true there is much to be learned as yet, but even so proper engineering development of the right kind must not be turned aside as worthless.

Yard handling, charging, hot metal transportation, mold conveying, sand handling and distribution, return of flasks, etc., to the molding machine, conveying cores, shakeout, knockout, conveying of castings to the cleaning room, handling in and out of the cleaning room, and so on, all demand some sort of material handling whether by wheelbarrow or highly developed machine.

We must not fail to consider all items even in the small foundry where, though we may not place as much labor-saving equipment as we would like, still there is usually some place to install some kinds of it. The extreme amount of material handling to produce one ton of finished castings cannot but help impress us of the necessity for this.

The Application of the Electric Truck to Material-Handling in the Foundry

By Harold J. Dorus* and C. S. Schroeder,* Stamford, Conn.

The ever-growing demand for mechanical substitutes for the human element in the foundry has brought home to all those who are connected with this phase of industry, the well recognized fact that increased production with the resulting reduced costs will be the benefits derived from such mechanical devices when the demand for, and the application of, the various pieces of equipment have been analyzed, the savings estimated, and such savings have been found to be sufficiently great to warrant such an installation.

A considerable part of the expense with which those responsible for the economic operation of the foundry have to deal with, is represented by the item called "Non-productive help," and it is this item that we will endeavor to prove can be materially assisted by the installation of an electric industrial truck.

A brief abstract of the operation of an industrial electric truck in a typical small foundry follows:

General Foundry Use

An elevating platform truck is first put to work bringing the facing sand to the squeezer molder, assuming at this point that there has not been installed an overhead sand conveying device in the foundry. The truck has been loaded in the sand facing room with tote boxes containing the grade of facing sand required for

*The Yale and Towne Mfg. Co.

the various jobs and the matter of correct distribution to the molders is a speedy and simple performance, doing away with the usual foundry laborers assigned to this job.

Having completed this task the truck is next assigned to gathering foundry refuse which has been placed in metallic containers which are skidded (of the type shown in Fig. 1), so that an elevating platform truck is quickly run under the skids, after which the refuse is taken to the auto truck and is at this point elevated to the necessary height for dumping into the truck. One can readily estimate the savings effected in this one daily operation which was in most instances performed by the wheelbarrow and laborers at considerable expense.

The castings spread on the floor after the previous day's heat are now placed in trays and loaded on the truck which is then driven to the tumbling-barrel room and unloaded. This requires considerable less time than formerly and is handled by the truck driver and a floor helper. The necessary trips having been made to the tumbling-barrel room now leaves the truck available for general foundry work, such as getting flasks, bottom boards, patterns, sea coal, pig iron, etc. As the tumbling-barrels are unloaded, the castings are trucked to the sorting and inspection benches, from which place the scrap is trucked to the cupola and the good pieces are sent to their proper destination. All of these transfers are made with the least possible chance of error as the truck driver is well acquainted with the foundry.

If the floor scales used for weighing coke, pig iron, scrap, etc., and the elevator to the charging platform have sufficient carrying capacity to handle the load, then the truck can be loaded with charges for the cupola, and, to avoid confusion, these same charges can be brought to the charging floor on their own individual skids. Fuel charges for the cupola can be weighed up in like manner and the ratio of fuel to metal kept accurately.

Value Lies in Ability to Reduce Cost of Operation

It is generally recognized that the only value that can be placed upon material-handling equipment of any kind lies in its ability to reduce cost of operation. It must either cut down the number of men in the material-handling personnel, or it must save

cost indirectly by the reduction of breakage of product, or it must reduce the dangers and hazards to the employes, or it must allow more efficient operation for productive employes through better service or more room in which to operate.

When material-handling equipment shows a profitable return on the initial investment as based on labor studies which can be quite accurately made, a manufacturer is losing profit every day he delays action.

What constitutes a profitable return on an investment for new equipment would be dependent to a great extent on the type of the equipment considered and the nature of the business involved. Basic improvements, such as concrete roadways, standard gauge railroad track, overhead crane equipment, which may be necessary in order to carry products of unusually heavy weight, are all improvements which must be incorporated in manufacturing establishments if they are to do business at all. In cases of this kind the improvements must be made irrespective of whether they will pay for themselves in one year or in ten years. Due to their basic nature, they are seldom figured on a basis of saving, but merely figured as a plant investment necessary to do business.

When the installation of material-handling equipment is not classed as basic but comes under the classification of improvements to existing and going manufacturing establishments, the computed return on the investment should be larger. Equipment of this nature is generally more subject to change or obsolescence, and therefore is rightfully figured to show a saving in a relatively short period of time. On electrical industrial trucks, our experience has shown that the customers require that the saving pay for the equipment in from one to three years of operation. In cases where the products of the user are unstable and subject to change in both tonnage and in character, we have generally found that all equipment must pay for itself within a year. But with more stable operations where conditions seldom change, equipment is usually bought on a basis of saving its cost over a period of three years' operation.

The next factor of importance is to form an opinion of the

probable accuracy with which the estimate has been made. In other words, if a system is contemplated which has been proved by actual use, in some other plant, saving calculations can be made quite accurately. In most cases the computed savings will vary only because of the fluctuation in business output. The variation in the effciency of operation between two similar plants is very small, as in practically all mechanical equipment there is but little skill required for efficient operation. It is seldom that more than one month is required to properly train an organization to new methods of material handling.

Where equipment is radically new and untried, it is quite natural to require a larger return in order to compensate for the uncertainty which may exist. Frequently, however, a new use of this kind, which proves successful will show many savings and many conveniences in addition to those which were figured for it, as it is the modern practice of all material-handling equipment manufacturers to be conservative in their estimates of what their products will do.

In this paper we will confine our discussion to actual installations of electric industrial trucks in foundry service. The references which follow have been tried and proved in foundry operation and it is our intent to present the information in such a way that foundry operators may find a clue that will show them how to reduce the cost on many material-handling operations in their own plants.

Each of the various operations which are fundamental to every foundry has been treated as a distinct and separate operation, although in actual practice, especially in smaller foundries, many of these operations may be performed by only one truck. Wherever possible reference has been made to the approximate tonnage that may be carried by one truck if run continuously on the operation outlined. In foundries whose tonnage would not permit the use of a truck continuously on one of these operations it will be possible to determine approximately what portion or percentage of the day will be required for each particular operation, and in this way determine the extent of usefulness of the equip-

ment. A careful study of the several operations allows us to determine very closely the cost of doing the work with existing equipment. We know approximately the number of laborers required for each of the operations of material-handling, and if material-handling is done by direct labor, or productive labor at any stage of the operation, it is well worthwhile to have a study made to show what percentage productive labor is lost or wasted in material-handling. It is economy to have low priced labor for the material-handling and allow productive labor, which is considerably higher priced, to devote all its time to making product. In many plants we have found only two, three or four men who are directly employed for material-handling purposes, but upon making a further analysis we found that a fair percentage of the time of practically all of their productive labor (molders) was devoted to moving material. Inasmuch as many men were employed in productive work, this small percentage represented a cost of material handling more than twice which might be reflected by only considering the material-handling gang. To illustrate this, we point to the process of molders breaking up their molds and hauling their newly poured castings to a place where eventually they will be taken to the remaining processes by the regular material-handling gang. If all the material-handling were confined to mechanical equipment and a single group of material-handlers, the molders could continue molding a half hour or an hour longer per day and accomplish a greater amount of work without in any way sacrificing the quality of work done. The material-handling gang, which is a lower paid class of labor, could remain after the molders and do their clean-up and pick-up work without getting in the way of the molders, and without having the molders get in their way. This would mean a double schedule of time for labor, but in many cases would show a considerable profit.

Cost of Maintenance

In order to permit a comparison between existing costs of material-handling, and that which may obtain through the use of industrial trucks, it is important first to know the cost of main-

taining the electric truck itself. The Industrial Truck Association has analyzed the cost of operation equipment in a great number of plants, and in order to standardize on an equitable charge for equipment, the organization has chosen a figure of 50c per hour for maintenance. This means that the truck itself would ordinarily cost $4.00 per day for an eight-hour period. The figure chosen is somewhat higher than obtained in actual practice, but has been made liberal so that it will cover all types of machines, and the very hardest of service. The figure includes the cost of insurance, depreciation, interest on capital invested, repairs, battery maintenance, tires, and the cost of the electricity for charging.

FIG. 1

It also includes the investment and maintenance of suitable battery charging equipment.

Taking Raw Material to Storage

It frequently happens that in a plant which is laid out to take its raw material direct from freight cars, an over-supply of such material is occasionally received, which must be unloaded into temporary storage. Under ideal conditions such an operation would not exist, but frequently an emergency arises where an industrial truck greatly facilitates the handling for such emergency work. An industrial truck equipped with a dump body (Fig. 1) either mounted on the truck or mounted on an auxiliary skid,

will reduce the inconvenience of such a situation by handling the work more quickly with a smaller gang and saving considerable money in labor and possible car demurrage.

In smaller plants, the handling of sand is often done by electric industrial trucks only. Fig. 4. It is often found that the layout of the buildings, together with the tonnage handled, makes it impractical to install belt conveyors or other conveying equipment to handle the materials. While an industrial truck is not as economical as a well laid out conveyor system, for this class of work, it frequently makes possible an application of mechanical handling, which could be done in no other practical way. Where several kinds of sand and other raw material must be handled a conveyor system would become quite elaborate and require considerable tonnage to make the installation practical.

An electric industrial truck of either the elevating type or the straight load carrying type, equipped with proper bodies, can handle from 100 to 150 tons of loose material over an 8-hour period, carrying the material an average distance of 300 feet. If it is necessary to hand shovel in the dump body, it is our experience that approximately four men will be required to keep the dump body skids filled, while one operator with a truck carries them away.

Charging the Cupola

On large skip filled furnaces with larry cars and complete overhead equipment to take material from the storage yards to the furnace, there will be very little opportunity for employing an industrial truck for charging the furnace. It is possible that occasional emergency requirements may call for a truck from one of the other departments in the foundry, but for regular operation the automatic equipment is more satisfactory, if the tonnage is sufficient to use such equipment to full advantage.

For skip filled furnaces, not supplemented with yard equipment, electric trucks are very economical units for bringing material from the rough storage to the skip hoist. Where the tonnage carried is average and especially where yard conditions are

such that the material must be stored in widely separated regions, the industrial truck will often prove the most economical unit.

An elevating platform truck, equipped with a 34 cu. ft. dump body skid (Fig. 1) and also a supplement of other skids for carrying pig iron, can average from 100 to 200 tons of material moved per 8-hour shift. This would compare very favorably with hand labor, which would require three to four men to do a similar amount of work. Where trucks of greater capacity are used and where loading operations are more efficiently laid out, a greater tonnage may be handled and a greater saving shown.

In one plant making about 510 tons of pigs per day an installation of electric trucks has been as follows:

There are 39 charges per day split up into 78 sections, each section consisting of 13 tons of ore, 3½ tons of stone, and 6½ tons of coke. The ore and the stone are handled by three trucks with end dump bodies which have replaced seven men with buggies. Two trucks are used for handling coke. These are also equipped with dump bodies. This makes five trucks in all to handle the charging. The trucks require 15 drivers for the three shifts who can be recruited from almost any class of laborer, as compared with 45 specialized laborers who are more difficult to obtain. This operation, when figured out into industrial truck units, means that one truck will carry 120 tons of material for an 8-hour shift with one driver, as compared with the old method which required three specialized laborers for the same unit of work.

On smaller jobs, an elevating truck may be used to bring hand buggies to the elevator during the charging time and serve other parts of the foundry when not required for this work. The buggies can be so arranged that they may be lifted directly by an elevating type of truck and transferred from the pile of material in the storage yard directly to the elevator at the cupola. By using buggies or skids of this type the industrial truck need not be tied up waiting to be loaded, but is kept constantly on the run while at various sections in the yard laborers are filling the several dump bodies which will eventually be brought to the elevator by the electric truck. In this way the less expensive equipment only is tied up, leaving the machine to operate continuously.

In another foundry a 10-ton low lift truck is employed, using

a number of skids to deliver pig iron from storage to the elevator. This one machine showed a saving of $28.00 per day over methods previously employed. The use of a high capacity machine in this instance reduced the number of trips required of the truck and, as a consequence, reduced the congestion at the elevator and through the various aisles in the yard.

Carrying Molten Metal

In several foundries a relatively new use for the electric industrial truck has been found in carrying melted metal from the cupola to the molding floor, Fig. 2. In most cases the ma-

FIG. 2

chines are of the elevating type and carry the skid on which is mounted a ladle having a capacity of 2,000 to 2,500 lbs. of metal. The foundry runways should be properly paved in order to facilitate this, as well as other material-handling operations using trucks, so that the danger of spillage when carrying the hot metal would be reduced, eliminating any undue hazards to the workmen. Where such an application has been used, it is found that the increased speed of the truck, together with the fact that it only requires one operator to move the heavy load, greatly speeded up the delivery of metal to the molding floors. In one particular foundry they have reported an increase in total capacity of 30 per

cent by releasing the overhead equipment. In another installation, we find that five trucks, equipped with ladle skids, deliver a 40-ton heat in three hours.

Inasmuch as these machines are of a general purpose type, they are applied for the remainder of the day in other material-handling activities. Each of the trucks is scheduled so that the various drivers know exactly what is expected of them at any given time of the day and automatically assemble when the time arrives for carrying metal. It has been definitely demonstrated that an electric industrial truck can carry a hot ladle over ordinary floors without danger of spilling the metal.

Carrying Cores

In the average foundry it is found necessary quite frequently

FIG. 3

to have the core making department separated a considerable distance from the molding floor. This entails the carrying of fragile cores from the core room to the molding floor.

For carrying cores a truck is usually equipped with a series of rack skids having a number of trays and provided with legs adapted for operation with an elevating truck. These racks very frequently are employed to carry the trays of green cores to the ovens and run them directly into them. After the cores are baked

the electric truck will bring the racks with the cores in place to the storage room. Where production is large it is profitable to use the rack for storing the cores. From storage they are again brought by the same truck to the molding floor and distributed as necessary to the various molders. In large production work one molder or one series of molders may receive an entire rack of cores, whereas in smaller production work the trays may be distributed individually to a number of molders. See Fig. 3.

The experience of all foundrymen who have substituted the electric method for the older hand method has been that the electric truck has reduced breakage an appreciable extent. The rub-

FIG. 4

ber-tired wheels of the industrial, together with the spring suspension, which is part of practically every machine, makes easier riding than would be the case with hand-pushed equipment, especially when provided with small diameter wheels. On hand-pushed equipment the tendency for the laborer is to rush over any holes or unevenness in the pavements, and when this is done with small iron wheels the jolt given the load is far more severe than with an electric machine which can be driven slowly when covering any extremely rough spots in the pavement.

By virtue of the fact that the operator of the truck stands a considerable distance from the load he is well protected against

the heat of the baking oven and racks of cores may be taken direct from the furnace without discomfort.

Carrying Sand to Molders' Benches

In foundries where the tonnage of material handled is not sufficient to warrant a conveyor system, electric industrial trucks, equipped with a dump body skid, are a very practical means of distributing the various kinds of sand to the molders' floor, Fig. 4.

FIG. 5

The flexibility that may be obtained by the use of an industrial makes it possible to deliver a quantity of each of the various kinds of sands, stored in several different bins, in the proper quantity and to the proper place. The truck driver soon becomes accustomed to the requirements of the various sections of the molding floor, and functions to automatically distribute the various classes of material as is required.

In one installation, the trucks were run on rails, and equipped with a large hopper body having a discharge through the center of the frame of the machine and between the rails. There were

openings in the floor of the trestle which allowed the sand to discharge directly into a hopper above the molder. The truck would be driven to receive its load from the proper bins, then run along the track and discharge it as required.

Carrying General Foundry Refuse

General refuse which is constantly accumulating in the foundry, such as burnt sand, may be very conveniently and quickly gathered by a truck of the elevating type, and discharged directly to the level of a dump body street vehicle or directly to a dump in the yard. A high lift elevating truck (Fig. 5) greatly facilitates these operations, as it permits dumping directly to the level of

FIG. 6

the street vehicle, or else allows the operator to dump in a pile of some considerable height for later distribution about the yard.

Due to the relatively smaller quantities that are involved, it is often found economical to place steel barrels about the shop for the collection of this refuse at the various molders' floors, and later gather the loaded barrels on to a skid and carry them as desired.

Carrying Finished Molds

Electric lift trucks equipped with forks (Fig. 6) have proved practical and economical for carrying finished molds to a point in the foundry that was more suitable for pouring without the need of the molder doing any hand handling. This allows the

molders' floor to be kept clear and allows the mold to be poured at a better temperature. Baking molds for steel castings is made easy by providing a simple, flexible means of carrying the heavy but delicate load through the various operations.

Carrying Castings Within the Foundry

For the general run of foundry castings it is usually most suitable to carry them in tote boxes and employ a standard elevating platform truck. In some cases the boxes are equipped with a hinged tail gate (Fig. 7) so that they may be easily dumped for any successive operations.

These tote boxes would be placed where castings are shaken out either on the grating or on the molders' floor, and filled as conditions may require. As soon as skids are filled, they are carried to the next operation which may be for sand blast, or any of the various other operations that are necessary to a newly made casting.

FIG. 7

A very efficient means of operation in connection with the handling of finished castings is to use either open end tote boxes or else tote boxes equipped with a hinged tail gate. As the castings are made and taken out, they are directly loaded into these boxes. The electric truck automatically picks up the skid load and delivers it to the next operation, which may be the tumbling barrels. In front of the tumbling barrels is built a substantial in-

clined structure (Fig. 7) which serves as a support for the skids. As the skid is lowered by the high lift elevating type of truck, it rests on the inclined support and takes the angle of the incline. This angle is sufficient to allow the castings to be slid out of the tote box and directly into the opening of the tumbling barrels. The barrels themselves are elevated sufficiently above the floor to give sufficient clearance for a similar tote box placed under the barrel so that when the barrel is unloaded or dumped, the material will fall directly into the tote box where it may be conveniently carried away by the same industrial truck. For most efficient operation, it is desirable to have the capacity of the tote boxes and the tumbling barrels equal. In practical operation it is found

FIG. 8

very simple to keep a skid always in place above and below the tumbling barrel, so no delay will be caused when the barrel is ready to be loaded or dumped.

The same principle of the elevated inclined structure is also employed in casting inspection. The structure in this case is not as high above the floor as the tumbling barrels, but just sufficiently high so that the inspector sitting on an elevated bench can open the tail gate of the tote box and allow a given quantity of castings to come on the inspecting table. As these are inspected and passed, they are merely shoved into the empty tote box directly below the table and subsequently carried to the next operation.

The boxes from the inspector can be weighed or counted and molders credited for piece rates accordingly. By such a scheme or operation, a minimum amount of hand labor is required, both on the part of the inspector and in the transporting of the material.

Special Purpose Trucks for Handling Castings

Where a sufficient quantity of large heavy product or castings are made, it is frequently advisable to install an elevating truck of the special purpose type suitable for carrying the particular casting in question. In plants making large boiler sections,

FIG. 9

machines have been supplied having arms extending beyond the elevating platform of the truck which are so spaced as to hook directly into holes in the heavy castings (Fig. 8). In this way, the heavy castings are routed through the entire foundry without the necessity of hand labor. The savings which are made possible through the installation of such special purpose equipment as shown in the photograph are self evident, as the tonnage that may be carried by such an industrial truck when properly routed for efficient operation may run from 200 to 400 tons per day per shift, using only one operator.

Other types of machines which have been demonstrated to be thoroughly practical are both the heavy duty and light duty locomotive type crane trucks (Fig. 9). These machines are built with a capacity of from 1,500 to 3,000 pounds capacity, and will carry a load at a considerable outreach beyond the center line of the machine. Such a truck is found very useful in plants where overhead equipment is limited in its range of operation, as well as in plants that require some means of supplementing the heavier overhead equipment for carrying medium weight castings. A further use of this type of machine comes from its ability to tier

FIG. 10

or stack material to a considerably greater height in the yards than would be possible with any equipment other than an overhead crane. They have an additional advantage of permitting storage in sections of the yard which are not serviced by overhead equipment and will help considerably for any emergency work.

Charging Malleable Annealing Furnaces

Special purpose elevating trucks are available which furnish a very practical means of loading annealing furnaces in malleable iron foundries (Fig. 10). The machines are equipped with elevating prongs of sufficient strength to carry a stack of several annealing boxes. A machine of this type may be had in capacities from 3,000 to 5,000 pounds. They will be capable of turning in

short enough space to allow practical operation in the foundry and within the furnace.

As the annealing boxes are made up, properly filled and stacked, they are carried by these furnace charging trucks direct to the annealing furnace, and placed in position in the furnace without the necessity of hand labor. The machines will steer short enough to make use of all the available space in the furnace without an undue loss of time for maneuvering.

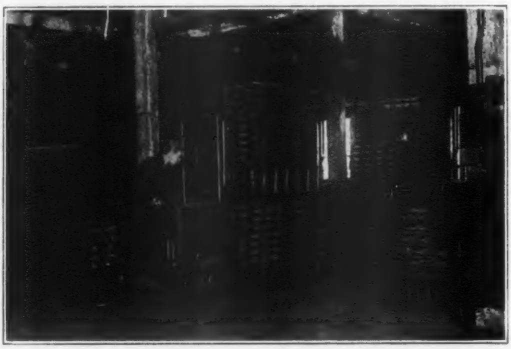

FIG. 11

The speed with which the furnaces may be loaded by electric trucks will greatly increase the tonnage of which the furnace is capable, due partly to the saving in loading time, and partly due to the fact that the furnace may be unloaded while still at a relatively high temperature, and also due to the fact that it does not require as long a period of time to again bring the furnace up to heat after it has been recharged.

In one malleable foundry, four electric industrial charging trucks carry 2,500 tons of boxes and castings over a period of twenty-four hours. The haul varies from 80 to 300 feet, and the loads carried vary from 3,000 to 4,000 pounds each. In a test run in this foundry, 900 stacks weighing 3,300 pounds each, or a total of 1,500 tons carried in 5¼ hours by two trucks, or 140

tons per hour per truck. The trucks were able to enter the furnace after having cooled to about 600 or 700 degrees Fahr. Allowing time out for delays it will readily be seen that an average figure of 300 tons per day is conservative.

In another annealing furnace, having a capacity of 36 tons, it has been found that the furnace may be unloaded by one truck and one driver in one hour and loaded in ¾ hour, or a total of 1¾ hours per charge carrying the pots approximately 600 feet. This represents 21 tons per hour for one truck. The lower figure is due to the length of haul and the small loads handled. In this particular installation, a standard high lift elevating machine was employed, using quickly detachable arms so that trucks could be

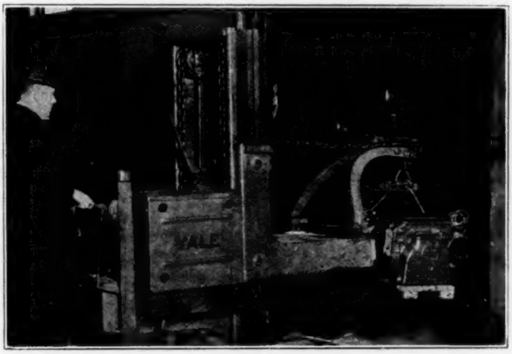

FIG. 12

used for general purpose hauling during the time when not required for filling the annealing furnace. The unloading time includes time necessary to attach the forks to a standard elevating truck.

Shipping

Where castings are shipped direct from storage to box cars, the usual method is to employ elevating type of truck (Fig. 11) and a number of dump body skids, tote boxes or flat platform skids. The nature of the skid employed depends largely on the type of product handled. Where castings are relatively small, it

is often found advisable to employ a heavy gauge dump body with a high lift elevating truck so that the machine may be elevated to its maximum height and the body dumped, throwing the castings into a pile of sufficient height to get full tonnage in the freight car. For shipments of less than carload lots and of miscellaneous heights, the flat platform type of skid is most suitable, as it allows a very wide variation in operating conditions.

In foundries where occasional large castings must be put in box cars, a quickly detachable jib crane (Fig. 12) may be installed on the high lift elevating platform of the truck, so that the large castings can be carried directly to the floor of the freight car without hand labor. After the cars are thus loaded, the attachments can quickly be removed and the truck used for regular operations in which it carries the skids.

These few descriptive operations of use of industrial trucks in foundries are only typical of many other possibilities. It has been our experience that, once an industrial truck is part of a regular foundry equipment, many other uses are immediately found for it. For example, in several foundries, the dropping of the cupola bottom after the heat has been drawn is accomplished by attaching the draw bar of an industrial truck by means of a chain to the bottom support, and starting the truck. Several sharp jerks usually accomplishes a task that would require ten or fifteen minutes' time for several men.

It is hoped that the illustrations cited may give a clue to better handling methods. Each example given has been proved in actual service to be a labor saver and this discussion has been given primarily to show what some others are doing and serve as a guide for your own plans.

Temperature Measurements of Molten Cast Iron*

By H. T. Wensel[1] and W. F. Roeser[2], Washington, D. C.

Introduction

The temperature of molten cast iron may be measured by means of a thermocouple, an optical pyrometer, or a radiation pyrometer. Of these three the thermocouple gives perhaps the most satisfactory values but involves the greatest trouble and expense.

Platinum to platinum-rhodium thermocouples, in suitable protecting tubes, can be used up to 1600 degrees Cent. (2900 degrees Fahr.). At high temperatures, however, they deteriorate rapidly and in molten iron any of the protection tubes now available have only a short life. The expense of replacing or recalibrating the couples and the labor and expense of frequently renewing the protection tubes rule out the rare-metal couple as an instrument for general use in molten iron and steel.

There is no upper limit to the range of usefulness of optical or radiation pyrometers. When used upon metals in the open, however, these pyrometers are subject to corrections which may seriously reduce their usefulness, unless these corrections be properly taken into account.

Optical and radiation pyrometers are usually calibrated to

*Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

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read correctly when sighted upon objects inside a hollow enclosure of sensibly uniform temperature, such as a furnace with an opening small in comparison with the area of the walls. Under such conditions, usually referred to as black body conditions, the pyrometer receives not only the energy radiated by the object sighted upon, but also energy radiated by other portions of the furnace and reflected by the object. In such a furnace the lack of energy radiated by a body is in every case exactly compensated by the energy reflected from the walls since bodies which have a low radiating power always have a correspondingly high reflecting power. Under black body conditions, therefore, the light received by the pyrometer is independent of the radiating characteristics of the materials and depends only upon the temperature.

When sighted upon a surface in the open, a pyrometer receives only the energy radiated by the object itself, and, consequently, always reads low. The ratio of energy radiated by a surface in the open to that radiated by a black body at the same temperature is known as the emissivity of the surface. For example, the emissivity of an unoxidized iron surface is about 0.4 while the value generally accepted for iron oxide (solid) is about 0.9. At 1400 degrees Cent. (2500 degrees Fahr.) this corresponds to a correction of 110 degrees Cent. (200 degrees Fahr.) for iron and 15 degrees Cent. (25 degrees Fahr.) for iron oxide when observed in the open with an optical pyrometer. The corresponding corrections in the case of a radiation pyrometer are about four or five times as great as those given above. The indications of this instrument are, therefore, so greatly affected by changes in emissivity as to render it unsuitable for temperature measurements of molten metals in the open.

It has been the practice to apply the corrections recommended by Burgess[1] to observations taken on iron and steel with an optical pyrometer. Burgess recommends using the value 0.40 for the emissivity of streams of apparently clean iron instead of the value 0.37 for pure iron obtained by him[2] under laboratory

[1] Burgess, G. K., Bureau of Standards Technologic Paper No. 91; 1917.
[2] Burgess, G. K., Bureau of Standards Bulletin No. 11; p. 591; 1915.

conditions. He gives the emissivities of liquid and solid iron oxide at 0.53 and 0.92 respectively. Liquid slag is stated to have "a variable emissivity of uncertain limits, depending on composition, but probably usually ranging between 0.55 and 0.75." Table 1 contains some of the values for these substances obtained by various investigators.

There is some question as to whether observations made on pure iron and iron oxide under laboratory conditions are applicable to commercial foundry practice. One cannot be sure that the surface being observed is the same as one of those studied in the laboratory until this has been checked under actual foundry conditions. The values given by Burgess were obtained under laboratory conditions, while those of Fry and of Moeller were obtained under service conditions.

Greenwood[8] has reported numerous pyrometer readings taken during steel making and iron casting. His temperature measurements are all relative, however. He determined the emissivity of slag relative to that of iron. Using the value 0.4 for iron, he finds 0.56 as the emissivity of slag.

Recently Wenzl and Morawe[9] have obtained results which led them to the conclusion that an optical pyrometer requires a correction of only 10 degrees Cent. to indicate the true temperature of ladles and streams of molten cast iron in commercial work. For obtaining true temperatures in the furnace they used a rare metal thermocouple protected by a quartz tube with an outer tube of carborundum (Silitrohr). For measurements in streams, the measuring junction of a platinum to platinum-rhodium couple was sealed into a thin quartz tube by means of a welding torch, forming a very thin protective coating to reduce thermal lag.

The carborundum tube, of course, was dispensed with here. They also used iron to contantan and iron to nickel couples with apparent success. The former failed at about 1380 degrees Cent.

[8] Greenwood, Cam. Schol. Mem. XII, p. 27; 1923.
[9] Wenzl and Morawe, Stahl and Eisen, p. 867; 1927; also Rev. d. Fond. Mod., p. 369; Sept. 25, 1927.

and the latter at about 1250 degrees Cent.

Simultaneous readings were obtained with a thermocouple inserted in the stream or ladle and with optical pyrometers calibrated for black body conditions. All the observations reported were taken below 1380 degrees Cent. and resulted in corrections of about 10 degrees. One observation at 1370 degrees, in which

Table 1

EMISSIVITIES FOR $\lambda = 0.65$ (RED LIGHT)

Substance	Temperature Deg. C.	Emissivity	Observer	Date
	800	0.63 solid		
Pure Iron	1000	0.54 solid	Bidwell[3]	1913
	1200	0.43 solid		
	1200	0.23 liquid (Undercooled!)		
	1400	0.38 solid		
	1400	0.31 liquid (Undercooled!)		
	1800	0.48 liquid		
	700	0.27 solid		
Pure Iron	1200	0.29 solid	Bidwell[4]	1914
	1300	0.29 liquid (Undercooled!)		
	1500	0.35 liquid (Undercooled!)		
	1800	0.53 liquid		
	1050	0.379 solid		
Pure Iron	1530	0.360 solid	Burgess[2]	1915
	1535	0.365 liquid		
Commercial Iron and Steel	1150–1700	0.45 liquid	Fry[5]	1924
Commercial Iron and Steel	750–1600	0.435	Moeller, Miething and Smick[6]	1925
Iron Oxide	1200	0.63 solid	Burgess[2]	1915
	1610	0.53 liquid		
	800	0.98 solid		
Iron Oxide	1000	0.95 solid	Burgess and	
	1200	0.92 solid	Foote[7]	1915-16
Oxide on Ordinary Iron and Steel	750–1500	0.6 solid		
Oxide on Stainless Steels	700–1400	0.7 solid	Fry[5]	1924
Iron Oxide	1100–1600	0.9 liquid		
Iron Oxide	840–1200	0.8 solid	Moeller et al.[6]	1925
Slags	....	0.55 to 0.75	Burgess[1]	1917
Slags	....	0.9	Fry[5]	1924

[2] Burgess, Bull. Bureau of Standards, 11, p. 591; 1915.
[3] Bidwell, Phys. Rev. (2), 1, p. 482; 1913.
[4] Bidwell, Phys. Rev. (2), 3, p. 439; 1914.
[5] Fry, Stahl and Eisen, 44, p. 1783; 1924.
[6] Moeller, Miething and Smick, Z. f. techn. Phys., 6, p. 644; 1925.
[7] Burgess and Foote, Bull. Bureau of Standards, 12, p. 83; 1915-1916.

the optical pyrometer read 92 degrees low, was rejected because the observation was taken through a veil of smoke.

Wenzl and Morawe report also measurements made during the pouring of a 19-ton forging ingot. The optical measurements on the pouring stream yielded 1420 degrees Cent. while the true temperature of the ingot just after pouring, was 1495 degrees or 75 degrees higher. They state that "this does not seem to rule out the fact that the correction factor hitherto used (in this case about 120 degrees) applies here because the steel must have experienced a cooling in the long time of pouring." While these authors have shown that the corrections to be applied below 1350 degrees Cent. true temperature are small, their work should not be taken to indicate that the corrections above 1400 degrees Cent. are of the same order of magnitude.

Recently, Herty[10] and others working at the Bureau of Mines measured the true and apparent temperatures on a bath of pig iron by sighting with an optical pyrometer on the free surface and on the bottom of a closed silica tube in a graphite casing immersed in the molten metal. They obtained a smooth correction curve varying from 95 degrees at 1400 degrees Cent. to 120 degrees at 1600 degrees Cent. They apparently made no readings below 1390 degrees Cent. true temperature.

The results of Herty and of Wenzl and Morawe are not necessarily contradictory, even though Herty found corrections more than ten times as great as those of the other two. The temperature ranges in which these observers worked overlap at only one point, namely, the observation of Wenzl and Morawe on the 19 ton forging ingot where the correction was found to be in agreement with Herty's results.

While it is, of course, desirable for some purposes to know the true temperature of iron and steel, the apparent temperature (uncorrected optical reading) would serve equally well for the purpose of temperature control if, at a given temperature, the optical reading were always low by the same amount. It has been the experience in some foundries, however, that the optical

[10] Herty et al., Bulletin Carnegie Inst. of Techn. 34; p. 52; 1927.

pyrometer readings in the neighborhood of 1300 degrees Cent. are not reliable even for temperature control. In one large pipe foundry, for example, it has been found that no trouble is encountered when pouring is done below 1320 degrees or above 1355 degrees Cent. apparent temperature but, around 1340 degrees Cent., pouring at the scheduled pyrometer reading does not always produce the same result.

At the request of and in cooperation with the sub-committee on cast iron research of the American Foundrymen's Association, the Bureau of Standards undertook to determine the corrections to be applied to the optical pyrometer readings on molten cast iron with particular reference to the constancy of these correc-

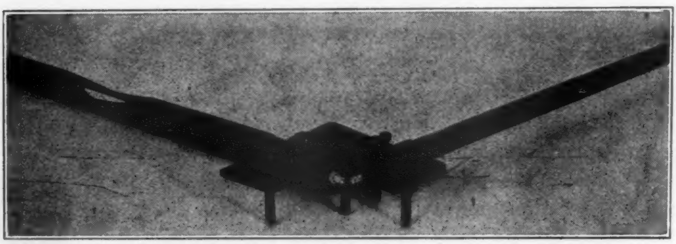

FIG. 1—THERMOCOUPLE SHOWING ARRANGEMENT OF PORCELAIN AND GRAPHITE TUBES. A PORTION OF THE GRAPHITE TUBE IS CUT AWAY TO SHOW THE PORCELAIN TUBE

tions at a given temperature. It was requested that nickel and nickel-chrome irons be included in the investigation as particular difficulty had been encountered in making optical pyrometer measurements on these irons.

Measurements in Commercial Foundries

Some preliminary observations were made at the Lynchburg Foundry Co., Lynchburg, Va., in connection with some other work being done by the committee mentioned above.

Five distinct mixtures of cast iron were investigated. Optical pyrometers were sighted upon the surface of the metal in ladles to obtain the apparent temperature and a platinum to platinum-rhodium thermocouple was used to obtain the true temperature. The thermocouple wires were threaded through two-hole porce-

lain insulating tubes and were protected by a porcelain tube inside of a graphite tube. (See Fig. 1.) The graphite tube was clamped at right angles to a long seamless steel tube to facilitate immersion in the molten metal. The thermocouples used were approximately 150 cms long of which a 50 cm length was inside the protection tubes and the remainder in the steel tube. The thermocouple was joined to extension leads in the steel tube, thereby locating the cold junctions at a portable potentiometer which was used for reading the emf developed.

The optical pyrometers used were of the disappearing filament type made by the Leeds and Northrup Company. The corrections obtained, thermocouple reading minus optical reading in the range 1360 to 1410 degrees Cent. (true temperature) varied from 90 to 100 degrees Cent. while in the range 1280 to 1360 degrees Cent. the corrections varied from 25 to 50 degrees Cent., indicating a higher emissivity at the lower temperatures. The results, however, were not conclusive. The apparatus and methods were in the experimental stage and the conditions were not as well controlled as in the work carried out later.

Further tests were then made at the plant of the American Cast Iron Pipe Co., Birmingham, Ala. Here essentially the same apparatus and methods were used under conditions which were better controlled than at Lynchburg. Observations were also made on streams in a few cases. Instead of holding the iron in ladles for obtaining observations, the iron was poured into dry sand molds, 10 inches in diameter and 10 inches deep rammed into a section of a 16-inch iron pipe. This was done to obtain relative cooling rates under uniform conditions and freezing points of the metal which were of interest to the foundrymen.

Several methods were used for obtaining measurements on streams. For observations on streams of special foundry iron, a 250-pound ladle was supported under the runner and the iron permitted to run into and overflow the ladle. The thermocouple was held in the ladle and optical pyrometers were sighted on the stream entering and leaving the ladle. The average of these latter values was taken as the apparent temperature of the iron.

For observations on blast furnace iron the thermocouple was

held in the molten iron at the slag dam and the optical pyrometer was sighted on the metal just as it flowed under the dam and into the runner.

Some observations were made on streams of pipe foundry iron by holding the thermocouple in the iron at the bottom of the stream entering a 3-ton ladle. The optical pyrometer was sighted on the stream at the lowest visible point. Other observations were made on the same iron by holding the thermocouple in a hand ladle held under the lip of the runner. Optical readings were made on the metal as it came over the edge of the ladle.

For obtaining observations on streams of monocast iron, a dam was built in the runner from the cupola. The thermocouple was held in a pool of metal ahead of the dam and the optical pyrometer was sighted on the stream as it came over the dam.

Table 2

TEMPERATURE READINGS TAKEN SIMULTANEOUSLY WITH THERMOCOUPLE AND OPTICAL AT BIRMINGHAM ON STREAMS OF FIVE TYPES OF IRONS

Type of Iron	Thermocouple Deg. C.	Optical Deg. C.	Difference Deg. C.
Monocast	1372 (4)	1360 (4)	12
Monocast	1381 (3)	1360 (3)	21
Pipe Foundry	1272 (4)	1249 (4)	23
Pipe Foundry	1288 (4)	1261 (4)	27
Pipe Foundry	1306 (5)	1293 (5)	13
Pipe Foundry	1308 (5)	1283 (5)	25
Pipe Foundry	1309 (3)	1295 (3)	14
Pipe Foundry	1312 (4)	1294 (4)	18
Pipe Foundry	1323 (6)	1310 (6)	13
Special Foundry	1374 (5)	1359 (5)	15
Special Foundry	1385 (5)	1319 (5)	66
Blast Furnace	1425 (7)	1323 (7)	102
Blast Furnace	1448 (5)	1341 (5)	107
American Radiator	1452 (6)	1363 (6)	89
American Radiator	1460 (5)	1371 (5)	89

Note: The figures in parentheses indicate the number of readings which were averaged to obtain the corresponding temperatures.

Some tests were also made on streams at the American Radiator Company, Birmingham, Ala. The thermocouple was placed in the mixer and optical pyrometers were sighted on the streams entering and leaving the mixer, the average being taken as the apparent temperature. The difference in temperature between the iron entering and leaving the mixer was always less than 20 degrees Cent.

The results of these tests on streams are given in Table 2 and Fig. 2. The corrections to the optical pyrometer for the true temperature range 1270 to 1375 degrees Cent. vary from 12 to 27 degrees Cent. One observation at 1385 degrees Cent. gave a correction of 66 degrees Cent. The other observations in the range 1425 to 1460 degrees Cent. yielded corrections varying from 89 to 107 degrees Cent.

The observations on ladles at Birmingham are shown in Table 3 and Fig. 2. All these observations were below 1340 degrees

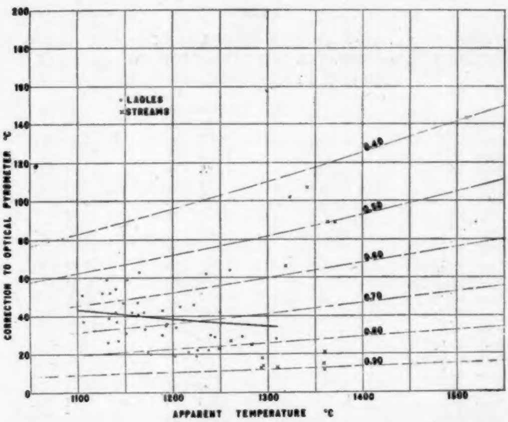

FIG. 2—RESULTS OF TESTS AT BIRMINGHAM. THE BROKEN LINES REPRESENT THE CORRECTIONS CORRESPONDING TO THE INDICATED EMISSIVITY VALUES FOR WAVE-LENGTH 0.65 MICRON. THE HEAVY LINE IS INTENDED TO REPRESENT THE OBSERVATIONS ON THE LADLES

Cent. true temperature and yielded corrections varying from 19 to 63 degrees Cent., the average of all these giving a curve with practically a constant correction of 40 degrees Cent.

The corrections to the optical pyrometer appear to be independent of the carbon content for total carbon contents from 2.76 to 3.77 per cent. On melt No. 459, which was run primarily to secure readings on an iron of high carbon content, it was impossible to secure more than two or three readings before the surface of the 3.77 per cent carbon iron was completely covered with graphite.

The chemical analyses, cooling rates and freezing points of the iron investigated at Birmingham are given in Table 4.

The temperature ranges covered in all the above tests were not very wide, as they had to be limited to those of the iron coming from the cupolas in the ordinary routine of the plant. However, the results of these tests indicated that the emissivities of streams of ordinary cast iron were much higher below 1375 degrees Cent. than above this temperature. In order to investigate

Table 3

TEMPERATURE READINGS TAKEN SIMULTANEOUSLY WITH THERMOCOUPLE AND OPTICAL AT BIRMINGHAM ON LADLES OF FIVE TYPES OF CAST IRON

Type of Iron	Thermocouple Deg. C.	Optical Deg. C.	Difference Deg. C.
Monocast, Run 450	1190 (3)	1131 (3)	59
Monocast, Run 450	1210 (3)	1151 (3)	59
Monocast, Run 450	1228 (3)	1165 (3)	63
Monocast, Run 450	1268 (3)	1222 (3)	46
Monocast, Run 450	1292 (2)	1250 (2)	42
Monocast, Run 451	1197 (3)	1177 (3)	20
Monocast, Run 451	1221 (4)	1202 (4)	19
Monocast, Run 451	1260 (3)	1238 (3)	22
Monocast, Run 455	1196 (3)	1149 (3)	47
Monocast, Run 455	1230 (4)	1194 (4)	36
Monocast, Run 457	1212 (3)	1170 (3)	42
Monocast, Run 457	1238 (3)	1204 (3)	34
Monocast, Run 457	1270 (3)	1240 (3)	30
Monocast, Run 461	1178 (3)	1126 (3)	52
Monocast, Run 461	1194 (3)	1140 (3)	54
Monocast, Run 461	1210 (3)	1163 (3)	47
Monocast, Run 461	1228 (3)	1193 (3)	35
Monocast, Run 461	1249 (3)	1211 (3)	38
Monocast, Run 461	1273 (3)	1244 (3)	29
Monocast, Run 461	1302 (3)	1273 (3)	29
Monocast, Run 461	1337 (3)	1309 (3)	28
High Carbon, Run 459	1253 (2)	1208 (2)	45
Special Foundry, Run 456	1143 (3)	1106 (3)	37
Special Foundry, Run 456	1172 (3)	1133 (3)	39
Special Foundry, Run 456	1205 (4)	1164 (4)	41
Special Foundry, Run 462	1178 (3)	1141 (3)	37
Special Foundry, Run 462	1204 (4)	1171 (4)	33
Special Foundry, Run 462	1238 (4)	1217 (4)	21
Pipe Foundry, Run 452	1156 (3)	1105 (3)	51
Pipe Foundry, Run 452	1182 (4)	1140 (4)	42
Pipe Foundry, Run 452	1232 (3)	1189 (3)	43
Pipe Foundry, Run 454	1158 (2)	1132 (2)	26
Pipe Foundry, Run 454	1182 (3)	1151 (3)	31
Pipe Foundry, Run 458	1170 (3)	1143 (3)	27
Pipe Foundry, Run 458	1195 (3)	1174 (3)	21
Pipe Foundry, Run 458	1244 (4)	1225 (4)	19
Pipe Foundry, Run 458	1248 (3)	1226 (3)	22
Low Carbon Cast, Run 460a	1297 (3)	1235 (3)	62
Low Carbon Cast, Run 460a	1324 (4)	1260 (4)	64
Low Carbon Cast, Run 463	1186 (3)	1134 (3)	52
Low Carbon Cast, Run 463	1199 (3)	1157 (3)	42
Low Carbon Cast, Run 463	1219 (3)	1189 (3)	30

Note: The figures in parentheses indicate the number of readings which were averaged to obtain the corresponding temperatures.

Table 4

PROPERTIES OF CAST IRONS RUN AT BIRMINGHAM, ALABAMA

	Monocast					Pipe Foundry			Special Foundry			Low Carbon		High Carbon
	450	451	455	457	461	452	454	458	453	456	462	460 (a)	463	459
Total Carbon	3.55	3.55	3.42	3.58	3.69	3.60	3.60	3.57	3.58	3.64	3.63	2.76	3.37	3.77
Manganese	0.53	0.59	0.51	0.75	0.37	0.37	0.48	0.49	0.45	0.40	0.38	1.16	0.30	0.53
Phosphorus	0.71	0.70	0.72	0.68	0.70	0.81	0.84	0.79	0.74	0.78	0.75	0.12	0.54	0.77
Sulphur	0.093	0.092	0.092	0.081	0.085	0.072	0.069	0.058	0.076	0.067	0.067	0.099	0.084	0.057
Silicon	1.45	1.42	1.42	1.73	1.57	1.71	1.72	1.68	1.70	1.69	1.32	2.12	1.49	1.80
Copper	0.05	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.09	0.02
F. P. (solidus), Deg. C.	1149	1148	1161	1145	1139	1133	1135	1137	1136	1135	1138	1260	1212	1139
Cooling Rate, Deg. C./min. in	20.0	19.0	19.5	20.5	19.5	21.5	20.0	22.5	20.0	19.0	21.5	20.0	15.0	17.0
Temperature Range, Deg. C.	1291–1251	1276–1238	1245–1206	1261–1220	1294–1255	1197–1154	1195–1155	1230–1185	1235–1195	1220–1182	1268–1225	1318–1198	1221–1206	1257–1223

Table 5

CHEMICAL COMPOSITIONS OF CAST IRONS RUN AT BUREAU OF STANDARDS

	Ordinary Cast					Low Carbon	Nickel Cast				Nil-Cr Cast	
							Low Nickel		Med. Nickel	High Nickel	Low Ni-Cr	High Ni-Cr
	1	2	3	4	5	12	6	9	7	10	8	11
Total Carbon	3.54	3.35	3.40	3.33	3.10	2.48	3.25	3.40	3.40	3.40	3.10	3.30
Graphite Carbon	2.83	2.65	2.75	2.70	0.01	1.90	3.14	3.03	2.68	3.17	2.38	2.61
Combined Carbon	0.71	0.70	0.64	0.63	3.09	0.58	0.11	0.37	0.72	0.23	0.72	0.69
Manganese	0.20	0.72	0.25	0.26	0.49	0.56	0.73	0.72	0.71	0.65	0.68	0.69
Phosphorus	0.505	0.505	0.510	0.810	0.345	0.380	0.515	0.490	0.515	0.480	0.495	0.470
Sulphur	0.032	0.034	0.020	0.023	0.120	0.037	0.043	0.039	0.036	0.038	0.029	0.035
Silicon	1.52	2.16	1.18	2.10	0.44	1.39	2.27	2.23	2.29	2.25	1.87	2.15
Nickel	...	...	...	...	0.06	...	0.51	0.52	1.35	2.99	1.34	2.95
Chromium	...	...	...	...	...	...	...	...	...	...	0.56	0.95

this phenomenon on ladles, further work was carried out in the foundry of the Bureau of Standards where it was possible to vary conditions at will and to thoroughly cover a wider temperature range.

Experiments at the Bureau of Standards

Seven distinct types of cast iron, as shown in Table 5, were investigated in the experimental foundry of the Bureau. The iron was melted in a 300 pound capacity electric arc furnace. To obtain the corrections for streams, a thermocouple was held in the iron in the furnace while the optical pyrometer was sighted on the stream flowing out of the furnace into a ladle. Previous experiments had indicated that the difference in temperature between the iron in the furnace and in the stream was of the order of 10 degrees Cent. No correction, however, was made for this.

The optical pyrometer was sighted on the stream from the front, there being no smoke whatever present during any of the observations reported in this paper.

As soon as the ladle was filled, the thermocouple was transferred to it and simultaneous readings taken with the thermocouple and the optical pyrometer as the iron in the ladle cooled. The depth of immersion of the couple in the ladle was from 6 to 10 inches. Observations on streams at low temperatures were obtained by holding the couple in the ladle while the optical pyrometer was sighted on the stream flowing into a mold, pig bed, or back into the furnace.

In order to determine whether the depth of immersion was sufficient, the thermocouple was immersed 4½ inches in molten copper. The thermocouple at this depth of immersion indicated within one degree the correct freezing point of the copper.

The thermocouples and optical pyrometers used in the tests at Lynchburg and Birmingham were calibrated both before and after the tests. One of the couples used at Birmingham changed 5 degrees in calibration, a pro rata correction being made for this. In the work done at the Bureau, all the measuring apparatus used was calibrated before and after each run. The maximum change observed was 4 degrees in the case of a couple which had been used above 1600 degrees Cent. Usually the change was about 2 degrees Cent.

As a ladle of cast iron is allowed to cool from 1500 degrees Cent. to 1300 degrees Cent. true temperature, a marked increase in the surface brightness occurs. This change occurred in all the irons investigated at nearly the same temperature, approximately 1375 degrees thermocouple reading. In some cases the change was very abrupt, the transition from a surface of the uniformly low emissivity to a surface of uniformly high emissivity taking place within ten or fifteen seconds. If the bright surface, apparently a solid skin on top of the molten iron, was removed by skimming, the surface would be temporarily "dark" but would again become uniformly bright usually before a satisfactory optical reading could be obtained. The phenomenon is very striking, the increase in brightness being almost 100 per cent. In other cases, bright patches would begin to appear and slowly spread to cover the entire surface. In such cases, readings were taken on both the bright and the dark portions for temperatures somewhat below the transition point.

In one case, on runs 6 and 9 on low nickel iron, the dark and bright portions persisted side by side from about 1375 degrees down to the end of the run. This behavior probably caused the difficulty mentioned by the A. F. A. in their request that this type of iron be included in our work. At the lower temperatures the brightest portions were observed, although these were usually streaked with dark. The optical readings on these runs are consequently lower than would have been obtained if clear patches of bright surface had been observed. In the case of the high and medium nickel irons, with or without chromium runs 7, 8, 10, and 11, the transition was very sharp, the surface being uniformly bright from 1375 degrees down to 1250 degrees, at which point the bright surface began to break up into dark and bright regions. Here observations were made on both dark and bright portions but only the "bright" readings are reported. The slight increase in the corrections at the lowest points of runs 8 and 11 are probably due to the fact that in these cases the bright film grew very thick toward the end of each run and an appreciable temperature difference may have existed between the top and bottom of the film.

The temperature measurements obtained in the Bureau foun-

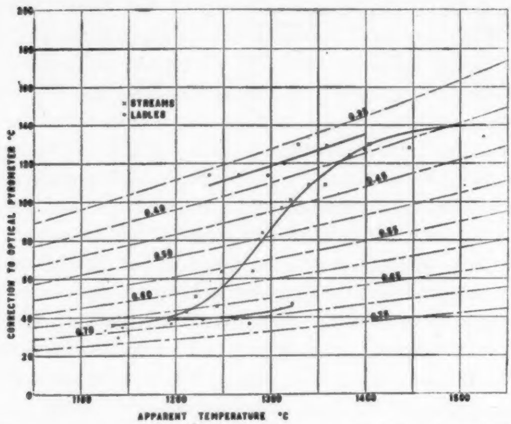

FIG. 3—RESULTS OF TESTS AT THE BUREAU OF STANDARDS ON ORDINARY CAST IRON. THE BROKEN LINES REPRESENT THE CORRECTIONS CORRESPONDING TO THE INDICATED EMISSIVITY VALUES FOR WAVE-LENGTH 0.65 MICRON

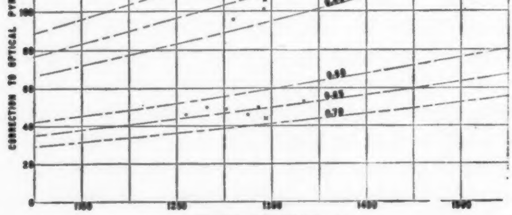

FIG. 4—RESULTS OF TESTS AT THE BUREAU OF STANDARDS ON CAST IRON CONTAINING ONE-HALF PER CENT NICKEL. THE BROKEN LINES REPRESENT THE CORRECTIONS CORRESPONDING TO THE INDICATED EMISSIVITY VALUES FOR WAVE-LENGTH 0.65 MICRON

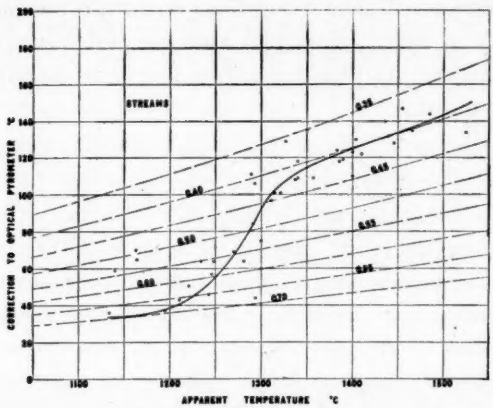

FIG. 5—RESULTS OF TESTS ON STREAMS OF THE SEVEN TYPES OF CAST IRON INVESTIGATED AT THE BUREAU OF STANDARDS. THE BROKEN LINES REPRESENT THE CORRECTIONS CORRESPONDING TO THE INDICATED EMISSIVITY VALUES FOR WAVE-LENGTH 0.65 MICRON

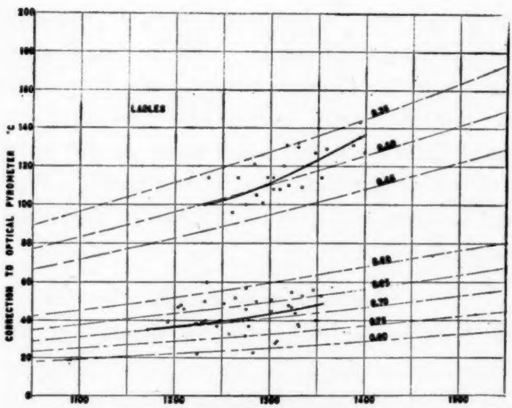

FIG. 6—RESULTS OF TESTS ON LADLES OF THE SEVEN TYPES OF CAST IRON INVESTIGATED AT THE BUREAU OF STANDARDS. THE BROKEN LINES REPRESENT THE CORRECTIONS CORRESPONDING TO THE INDICATED EMISSIVITY VALUES FOR WAVE-LENGTH 0.65 MICRON

dry are shown in Tables 6 and 7. Two sample runs are given graphically in Figs. 3 and 4 to show the discontinuity in the correction curve. In Figs. 5 and 6 are plotted all the data shown in Tables 6 and 7.

It will be noted that in Fig. 3, the corrections to be applied to streams do not show a sharp break. This may be explained by supposing that the surface observed is a mixture of light and dark portions, the result being the same as would be obtained if a ladle of the iron were vigorously stirred so as to keep the surface broken up. Above the transition point the surface is, of course, "dark." At low temperatures the corrections for the stream approach those for ladles. The streams observed at the Bureau were comparatively small and irregular. In large, steady streams, such as were viewed at Birmingham, the stirring action of the stream would be less and here the corrections are no larger than for ladles.

In streams of high nickel and nickel-chrome irons, large areas of uniformly high and low brightness could be distinguished side by side, these being the irons in which the bright skin formed quickly and hung together apparently as a comparatively tough solid film. The temperature range in which this could be observed on streams of these irons was comparatively narrow and the temperature of the stream could be estimated within a few degrees in this region merely by noting the presence of the bright patches among the dark.

Discussion of Results

While it is comparatively easy to establish the change in surface emissivity around 1375 degrees Cent. on cast irons, the explanation of the phenomenon is more difficult. One can only form a conjecture as to the composition of the surface. The transition may be from liquid to solid oxide or from liquid to solid slag. The emissivities around 0.4 obtained in this work at

the higher temperatures, however, seem to indicate that there we are dealing with a clean iron surface. At lower temperatures it is probable that the surface is made up to a large extent, if not entirely, of iron oxides.

It is a familiar fact[11] that in normal Bessemer blows, silicon is first oxidized and then carbon, while in blows that start at an initially high temperature, the silicon is eliminated after the carbon. Similarly in a basic open hearth heat, normally the phosphorus is taken out first and then the carbon, but by beginning a heat at a high initial temperature, the carbon may be removed first. This

[11] McCaffery, R. S., Trans. A. F. A., Vol. 35 (1927).

Table 6

TEMPERATURE READINGS TAKEN SIMULTANEOUSLY WITH THERMOCOUPLE AND OPTICAL IN BUREAU OF STANDARDS FOUNDRY ON STREAMS OF SEVEN TYPES OF CAST IRONS

Type of Iron	Thermocouple Deg. C.	Optical Deg. C.	Difference Deg. C.
Ordinary Cast, Runs 1 to 5, inclusive	1170 (2)	1134 (2)	36
Ordinary Cast, Runs 1 to 5, inclusive	1232 (3)	1195 (3)	37
Ordinary Cast, Runs 1 to 5, inclusive	1254 (4)	1211 (4)	43
Ordinary Cast, Runs 1 to 5, inclusive	1272 (3)	1221 (3)	51
Ordinary Cast, Runs 1 to 5, inclusive	1289 (4)	1243 (4)	46
Ordinary Cast, Runs 1 to 5, inclusive	1312 (4)	1248 (4)	64
Ordinary Cast, Runs 1 to 5, inclusive	1345 (6)	1281 (6)	64
Ordinary Cast, Runs 1 to 5, inclusive	1375 (2)	1291 (2)	84
Ordinary Cast, Runs 1 to 5, inclusive	1408 (2)	1311 (2)	97
Ordinary Cast, Runs 1 to 5, inclusive	1422 (7)	1321 (7)	101
Ordinary Cast, Runs 1 to 5, inclusive	1449 (3)	1340 (3)	109
Ordinary Cast, Runs 1 to 5, inclusive	1466 (2)	1357 (2)	109
Ordinary Cast, Runs 1 to 5, inclusive	1507 (4)	1383 (4)	124
Ordinary Cast, Runs 1 to 5, inclusive	1534 (2)	1404 (2)	130
Ordinary Cast, Runs 1 to 5, inclusive	1574 (2)	1446 (2)	128
Ordinary Cast, Runs 1 to 5, inclusive	1659 (1)	1525 (1)	134
Low Carbon, Run 12	1303 (3)	1246 (3)	57
Low Carbon, Run 12	1339 (1)	1270 (1)	69
Low Carbon, Run 12	1523 (3)	1400 (3)	123
Low Carbon, Run 12	1602 (5)	1455 (5)	147
Low Nickel, Runs 6 and 9	1338 (2)	1294 (2)	44
Low Nickel, Runs 6 and 9	1399 (2)	1293 (2)	106
Low Nickel, Runs 6 and 9	1458 (4)	1340 (4)	118
Low Nickel, Runs 6 and 9	1504 (4)	1386 (4)	118
Low Nickel, Runs 6 and 9	1532 (1)	1410 (1)	122
Low Nickel, Runs 6 and 9	1576 (5)	1436 (5)	140
Medium Nickel, Run 7	1199 (1)	1140 (1)	59
Medium Nickel, Run 7	1298 (2)	1234 (2)	64
Medium Nickel, Run 7	1445 (2)	1337 (3)	108
Medium Nickel, Run 7	1510 (2)	1400 (2)	110
High Nickel, Run 10	1233 (2)	1163 (2)	70
High Nickel, Run 10	1416 (2)	1315 (2)	101
High Nickel, Run 10	1509 (3)	1390 (3)	119
Medium Nickel-Chrome, Run 8	1375 (2)	1300 (2)	75
Medium Nickel-Chrome, Run 8	1400 (3)	1289 (3)	111
Medium Nickel-Chrome, Run 8	1456 (3)	1327 (3)	129
Medium Nickel-Chrome, Run 8	1629 (3)	1485 (3)	144
High Nickel-Chrome, Run 11	1229 (2)	1164 (2)	65
High Nickel-Chrome, Run 11	1572 (2)	1440 (2)	132
High Nickel-Chrome, Run 11	1601 (3)	1466 (3)	135

Note: The figures in parentheses indicate the number of readings which were averaged to obtain the corresponding temperatures.

Table 7

TEMPERATURE READINGS TAKEN SIMULTANEOUSLY WITH THERMOCOUPLE AND OPTICAL IN BUREAU OF STANDARDS FOUNDRY ON LADLES OF SEVEN TYPES OF CAST IRONS

Type of Iron	Thermocouple Deg. C.	Optical Deg. C.	Difference Deg. C.
Ordinary Cast, Runs 1 to 5, inclusive	1232 (4)	1193 (4)	39
Ordinary Cast, Runs 1 to 5, inclusive	1268 (4)	1229 (4)	39
Ordinary Cast, Runs 1 to 5, inclusive	1288 (4)	1248 (4)	40
Ordinary Cast, Runs 1 to 5, inclusive	1300 (4)	1260 (4)	40
Ordinary Cast, Runs 1 to 5, inclusive	1315 (5)	1278 (5)	37
Ordinary Cast, Runs 1 to 5, inclusive	1349 (4)	1235 (4)	114
Ordinary Cast, Runs 1 to 5, inclusive	1370 (4)	1323 (4)	47
Ordinary Cast, Runs 1 to 5, inclusive	1380 (4)	1266 (4)	114
Ordinary Cast, Runs 1 to 5, inclusive	1411 (4)	1297 (4)	114
Ordinary Cast, Runs 1 to 5, inclusive	1434 (4)	1314 (4)	120
Ordinary Cast, Runs 1 to 5, inclusive	1459 (4)	1329 (4)	130
Ordinary Cast, Runs 1 to 5, inclusive	1488 (4)	1359 (4)	129
Ordinary Cast, Runs 1 to 5, inclusive	1526 (4)	1399 (4)	127
Low Carbon, Run 12	1312 (3)	1272 (3)	40
Low Carbon, Run 12	1347 (3)	1302 (3)	45
Low Carbon, Run 12	1378 (3)	1323 (3)	55
Low Carbon, Run 12	1404 (3)	1283 (3)	121
Low Carbon, Run 12	1407 (2)	1354 (2)	53
Low Carbon, Run 12	1448 (3)	1317 (3)	131
Low Carbon, Run 12	1490 (4)	1350 (4)	140
Low Carbon, Run 12	1537 (3)	1394 (3)	143
Low Nickel, Runs 6 and 9	1256 (3)	1210 (3)	46
Low Nickel, Runs 6 and 9	1282 (3)	1232 (3)	50
Low Nickel, Runs 6 and 9	1301 (3)	1252 (3)	49
Low Nickel, Runs 6 and 9	1321 (3)	1275 (3)	46
Low Nickel, Runs 6 and 9	1336 (3)	1286 (3)	50
Low Nickel, Runs 6 and 9	1356 (3)	1260 (3)	96
Low Nickel, Runs 6 and 9	1387 (4)	1334 (4)	53
Low Nickel, Runs 6 and 9	1393 (4)	1292 (4)	101
Low Nickel, Runs 6 and 9	1461 (4)	1329 (4)	132
Medium Nickel, Run 7	1207 (3)	1172 (3)	35
Medium Nickel, Run 7	1251 (3)	1204 (3)	47
Medium Nickel, Run 7	1294 (3)	1234 (3)	60
Medium Nickel, Run 7	1316 (3)	1264 (3)	52
Medium Nickel, Run 7	1332 (4)	1275 (4)	57
Medium Nickel, Run 7	1353 (3)	1302 (3)	51
Medium Nickel, Run 7	1368 (4)	1320 (4)	48
Medium Nickel, Run 7	1374 (4)	1274 (4)	100
Medium Nickel, Run 7	1402 (3)	1346 (3)	56
Medium Nickel, Run 7	1411 (4)	1303 (4)	108
High Nickel, Run 10	1246 (4)	1224 (4)	22
High Nickel, Run 10	1319 (3)	1278 (3)	41
High Nickel, Run 10	1368 (3)	1330 (3)	38
High Nickel, Run 10	1417 (1)	1303 (1)	114
Medium Nickel-Chrome, Run 8	1282 (3)	1245 (3)	37
Medium Nickel-Chrome, Run 8	1307 (3)	1275 (3)	32
Medium Nickel-Chrome, Run 8	1337 (4)	1308 (4)	29
Medium Nickel-Chrome, Run 8	1368 (3)	1331 (3)	37
Medium Nickel-Chrome, Run 8	1390 (3)	1285 (3)	105
Medium Nickel-Chrome, Run 8	1429 (3)	1319 (3)	110
Medium Nickel-Chrome, Run 8	1474 (3)	1347 (3)	127
Medium Nickel-Chrome, Run 8	1529 (3)	1394 (3)	135
High Nickel-Chrome, Run 11	1255 (3)	1207 (3)	48
High Nickel-Chrome, Run 11	1273 (3)	1233 (3)	40
High Nickel-Chrome, Run 11	1291 (3)	1258 (3)	33
High Nickel-Chrome, Run 11	1306 (3)	1283 (3)	23
High Nickel-Chrome, Run 11	1334 (4)	1306 (4)	28
High Nickel-Chrome, Run 11	1371 (3)	1327 (3)	44
High Nickel-Chrome, Run 11	1389 (3)	1349 (3)	40
High Nickel-Chrome, Run 11	1418 (3)	1310 (3)	108
High Nickel-Chrome, Run 11	1442 (3)	1333 (3)	109
High Nickel-Chrome, Run 11	1468 (3)	1354 (3)	114
High Nickel-Chrome, Run 11	1518 (2)	1387 (2)	131

Note: The figures in parentheses indicate the number of readings which were averaged to obtain the corresponding temperatures.

points to the fact that the oxidation of the carbon in cast iron takes place to a large extent at high temperatures. This, occurring at the surface, might produce conditions sufficiently reducing to maintain a surface of metallic iron. At lower temperatures, the oxidation of the carbon taking place to a negligible extent would permit the oxide to form on the surface.

Another explanation offered is that the transition at 1375 degrees Cent. is from liquid to solid iron oxides. While the melting point of the various oxides of iron are all higher than this, we are undoubtedly dealing with a mixture or solution of FeO in Fe_2O_3 as shown by the work of Sosman and Hostetter. It is very likely than an eutectic would be formed melting in the neighborhood of 1375 degrees. However, the emissivity values obtained above this point indicate that here we have metallic iron. Perhaps the best explanation is that the solid oxide formed below 1375 degrees is comparatively insoluble in molten iron, while the molten oxide formed above this point goes into solution as fast as it forms.

With a little practice and judgment it is possible to determine when the iron is above or below the transition point without seeing the actual transition. The bright surface, below the transition point, is distinctly yellow and has a matte appearance, while above this point the iron has a mirror surface with a slightly greenish tinge. Where both bright and dark are present on a ladle, of course, no confusion should result, and when the surface is streaky, the correction made should be intermediate between large and small. In any case one can always skim off the surface and note how the brightness of the metal underneath compares with that of the surface which has been measured.

Where iron of a given composition is poured day after day the optical pyrometer should not give any serious trouble even in the transition range, provided the operator knows about the transition phenomenon and is on his guard.

The corrections to be added to apparent temperatures in order to obtain true temperatures will be found summarized in Tables 8 and 9 for both Centigrade and Fahrenheit scales. The data in these tables are based on an emissivity of 0.7 below and 0.4 above the transition point, which are recommended as being a fair average of all available data.

So far no work has been done on steels, but an analogous condition exists here. In fact, it was a knowledge of a similar

Table 8

CORRECTIONS TO OPTICAL PYROMETER IN DEG. C. WHEN USED ON MOLTEN CAST IRON ($\lambda = 0.65\ \mu$)

Apparent Temperature Deg. C.	Below Transition Point True Temp. Deg. C.	Below Transition Point Correction Deg. C.	Above Transition Point True Temp. Deg. C.	Above Transition Point Correction Deg. C.
1160	1194	34	....	...
1180	1215	35	....	...
1200	1236	36	....	...
1220	1257	37	....	...
1240	1278	38	....	...
1260	1299	39	1365	105
1280	1320	40	1387	107
1300	1341	41	1410	110
1320	1362	42	1433	113
1340	1383	43	1456	116
1360	1404	44	1479	119
1380	....	..	1502	122
1400	....	..	1526	126
1420	....	..	1549	129
1440	....	..	1572	132
1460	....	..	1595	135

Table 9

CORRECTIONS TO OPTICAL PYROMETER IN DEG. F. WHEN USED ON MOLTEN CAST IRON ($\lambda = 0.65\ \mu$)

Apparent Temperature Deg. F.	Below Transition Point True Temp. Deg. F.	Below Transition Point Correction Deg. F.	Above Transition Point True Temp. Deg. F.	Above Transition Point Correction Deg. F.
2120	2181	61	....	...
2156	2219	63	....	...
2192	2257	65	....	...
2228	2295	67	....	...
2264	2332	68	....	...
2300	2370	70	2489	189
2336	2408	72	2529	193
2372	2446	74	2570	198
2408	2484	76	2611	203
2444	2521	77	2653	209
2480	2559	79	2694	214
2516	....	..	2736	220
2552	....	..	2779	227
2588	....	..	2820	232
2624	....	..	2862	238
2660	....	..	2903	243

phenomenon occurring at a higher temperature in the case of steels which, to some extent, led to the method of investigation adopted here. It is hoped to take up the problem of optical pyrometer measurements on steel in the near future.

Summary

Measurements of the true temperature with a thermocouple and apparent temperature with an optical pyrometer on molten cast iron show that the character of the surface undergoes a change in the neighborhood of 1375 degrees Cent. true temperature. Observations on streams and ladles in the Bureau of Standards foundry and in commercial plants all indicate that the uncorrected optical pyrometer reading is approximately 40 degrees Cent. lower than the true temperature below 1375 degrees Cent. when the bright presumably oxidized surface is observed. This corresponds to an emissivity of 0.7 in this region. Above this region the emissivity is approximately 0.4, corresponding to a correction of 110 degrees at 1400 degrees Cent. and 140 degrees at 1600 degrees Cent. true temperature.

The change in emissivity is attributed to the formation of iron oxide below 1375 dgerees Cent. Above this temperature the difference between true and apparent temperature corresponds to the emissivity found for pure iron in the laboratory.

In conclusion the authors wish to acknowledge the cooperation of the American Cast Iron Pipe Company and the Lynchburg Foundry Company in providing opportunity for making measurements in their plants, and of the experimental foundry of the Bureau of Standards in making special heats for the purpose of this investigation. Particular acknowledgment is due Mr. J. T. MacKenzie, chairman of the Sub-Committee on Cast Iron Re-

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Sand Control Methods and Their Developments in a Light Casting Foundry

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All foundries are interested in the quality and costs of their castings, and the molding sand is very closely associated with both of these items. This paper is intended to show principally the practical application of the standard methods of sand testing to the control of molding sand in a large, light castings foundry of the mechanical handling type, and also developments which are directly associated with these tests.

Molding sand control must accomplish two purposes, it must act as a means of expression, so that records may be kept for future reference, and must be capable of setting and maintaining a standard which will result in an improvement in the quality and a reduction in the costs of the castings.

The methods of testing as outlined in this paper have been in effect for the past four years and have in our opinion eliminated one of the uncertain factors in the economical production of good castings.

The first step in sand control is an investigation to determine the sand requirements for the particular foundry in question. A study of this subject should be made by someone in the organization capable of this type of work until such time that a standard could be determined upon, and then the maintenance of the standard becomes a routine matter. Following the adop-

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tion of routine tests an observation of the results obtained generally suggests improvements and the organization is better fitted to take advantage of the developments as they come up.

Molding sand is intimately associated with the surface quality of the castings and the discount, resulting from blows, stickers, scabs, washouts, cold shut and drops. It is quite true that there are causes other than sand for some of these defects, but with the use of a suitable sand, properly controlled, one source of trouble is eliminated. The first consideration is surface quality, as this will place certain limitations on the sand that can be used. The surface quality is mainly affected by the grain size of the sand as used, moisture, quantity and distribution of the clay, method of sand handling and the fusion point. These properties of sand and their relation to the surface quality will be discussed under a section on molding sand tests and their application.

In order to maintain a definite surface quality in a mechanical handling system it becomes necessary to use either a mulled facing sand or a very large quantity of new sand to counteract the effects of this handling. We have found that an excellent surface can readily be produced by using nearly all new sand of the proper grain size, but this procedure is expensive.

The following tests are used both for control and investigation of the sand:

1. Tensile strength test on green sand.
2. Dry strength test.
3. Permeability test.
4. Moisture test.
5. Grade test.
6. Durability test.
7. Relative fusion point test.
8. Microscopic examination.

Molding Sand Tests and Their Application

Tensile Strength Test

Green strength in a molding sand is very important. The sand must possess sufficient cohesiveness to be moldable and must

conform identically with the pattern from which it was withdrawn. The apparatus used for this determination is similar to that employed by Grubb[1], and measures directly the cohesion between the sand-clay particles. For our purpose this apparatus gives very satisfactory results, but the A. F. A. bar test, compression and shear test also give good results. The green strength is mainly affected by the moisture, the quality, quantity and distribution of the clay.

Table 1 and Table 2 indicate the effect of moisture on the bond and permeability of molding sands.

Table 1

SAND USED FOR MAKING ONE-EIGHTH TO ONE-HALF INCH SECTIONS, A. F. A. GRADE 2D

Moisture	Tensile Strength lbs./in.²	Permeability
3.0	0.364	15.5
*4.0	0.490	17.5
†5.0	0.431	19.0
6.0	0.398	18.5
8.0	0.343	16.0

*Optimum Moisture Content (Tensile Strength).
†Optimum Moisture Content (Permeability).

Table 2

SAND USED FOR MAKING ONE-HALF TO ONE INCH SECTIONS, A. F. A. GRADE 3E

Moisture	Tensile Strength lbs./in.²	Permeability
3.0	0.522	30.5
*4.0	0.902	33.7
†5.0	0.834	34.0
6.0	0.730	33.0
8.0	0.627	31.5

*Optimum Moisture Content (Tensile Strength).
†Optimum Moisture Content (Permeability).

Maximum bond is obtained when the sand contains just sufficient moisture to saturate the clay, insufficient or excess moisture has a tendency toward lowering the bond and permeability.

Other factors affecting the strength will be discussed later.

Dry Sand Strength

As iron is poured into a green sand mold the latter is dried by the heat of the metal, and in this condition the sand must possess sufficient strength to resist the cutting and washing action of the iron.

[1] *Testing Foundry Sands,* Trans. A. F. A., Vol. 34, pp. 522-524, 1926.

For this test a block of sand is taken similar to that used for the permeability determination, baked at 150 degrees Cent. for one hour and the dry strength determined by compression.

Dry strength is dependent on the quality and quantity of the clay, organic and mineral binders, and especially upon the moisture content. The relation of moisture and clay content to dry strength is illustrated in the chart of Fig. 1.

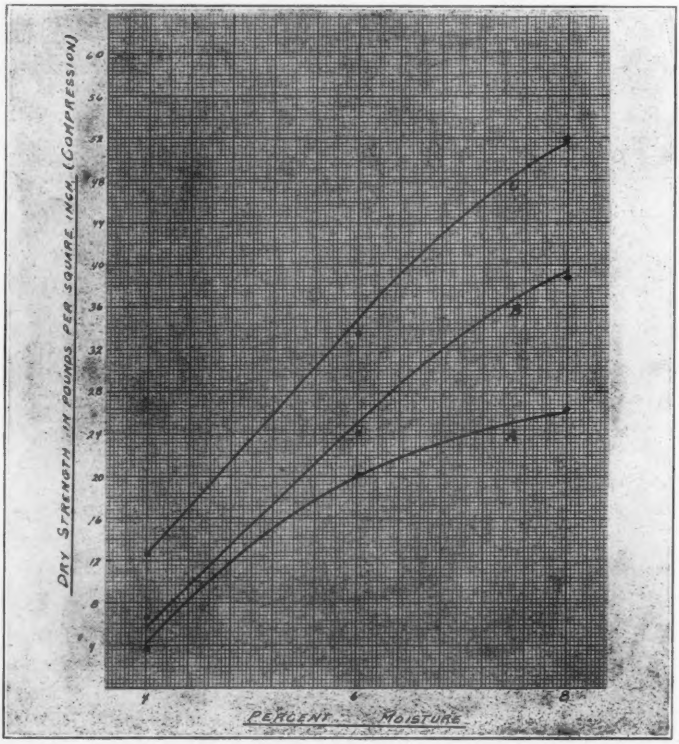

FIG. 1—CHART SHOWING DRY STRENGTH AND ITS RELATION TO THE MOISTURE AND CLAY CONTENT IN MOLDING SAND. A, SAND A. F. A. GRADE 2D, WITH 9.6 PER CENT CLAY SUBSTANCE; B, SAND A. F. A. GRADE 3E, WITH 11.5 PER CENT CLAY SUBSTANCE; C, SAND A. F. A. GRADE 4F, WITH 15.4 PER CENT CLAY SUBSTANCE

Dry strength may be increased, depending upon the quantity of clay and the moisture content of the sand.

Probably the most economical method to increase the dry strength in the majority of foundries is by the addition or use of a sand of high dry strength. Pitch binder is used advantageously in some very large foundries for increasing the dry strength, while others use a combination of pitch binder and high moisture content. The value of dry strength may be appreciated from the fact that an increase of 35 per cent in the dry strength has reduced by one-half the losses due to cuts on one particular type of casting.

Permeability

Permeability is the property of sand which allows the gases to escape through the mold, and it determines to a very large extent the discount of castings due to blows. The permeability is determined with the standard A. F. A. apparatus using a Dietert direct reading device, and the measure of this property in molding sand, as determined by this machine, gives very satisfactory results. A detailed description may be obtained in the Tentatively Adopted Standards of Test of the Joint Committee on Molding Sand Research.[2] The permeability of molding sand depends largely on the size and shape of the grains, moisture content, distribution of the clay or bonding material, sea coal and possibly other factors. For maximum permeability the grain size should be as uniform as possible and the surface quality is dependent to a large extent on the permeability; as a general rule, the greater the permeability the less desirable the surface quality. Care must be taken in making sea coal additions

[2] *Permeability Test*, Trans. A. F. A., Vol. 31, pp. 708-721, 1923.

as this material will tend to reduce the permeability.

Moisture Test

A great deal of care must be exercised in the tempering of molding sand, for casting losses and surface quality to a large extent depend upon the results of this operation. Moisture, as indicated in Table 1 and Table 2, is directly related to the bond and permeability and a large majority of foundries seem to recognize these effects in molding sand. Excess moisture aside from lowering the strength and permeability will create a considerable volume of steam when the iron enters the mold, therefore, moisture in excess of the amount which is necessary to develop the proper strength will make it more difficult to produce good castings due to the excess steam created.

The moisture in sand is determined by a modification of the Wolf-Grubb[3] method which is illustrated in Fig. 2. The method consists of passing heated air through a container filled with the sand to be tested and percentage loss in weight of the sand determined. The temperature is measured with a thermocouple

[3] *Molding Sand Reclamation and Control Experiments,* Trans. A. F. A., Vol. 32, pt. 2, pp. 9 and 12.

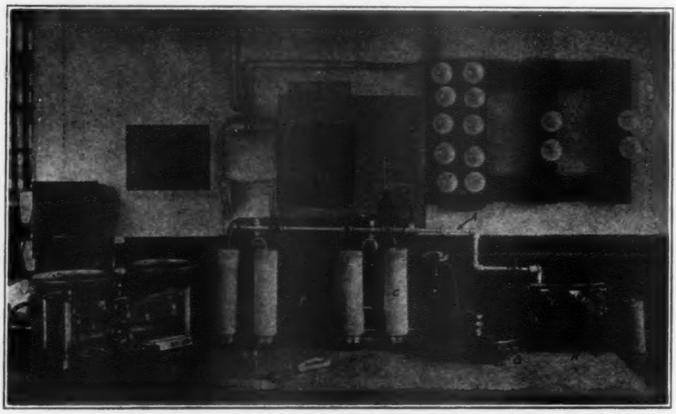

FIG. 2—MOISTURE TESTING APPARATUS. A, AIR LINE; B, PRESSURE GAUGE; C, HEATER; D, SAND CONTAINER; E, THERMOCOUPLE; F, SELECTIVE SWITCH; G, RHEOSTAT; H, POTENTIOMETER

and the pressure of the air with a mercury gauge, both factors being controlled within definite limits.

Moisture is also associated with surface quality. A mold made from dry or improperly tempered sand having insufficient cohesion to lift properly from the pattern results in loose sand in the mold and also the iron will tend to cut and wash the dry sand, both conditions causing an inferior surface. Excess moisture has a tendency to make the molten metal sluggish, impairing the fluidity and producing cold-shot castings.

Much has been said about the optimum moisture content in sands and it is well to consider this point. The optimum moisture content of a molding sand is that moisture content at which the sand exhibits its greatest bond or permeability. Table 3 compares the optimum moisture content with that moisture content which produces excellent results.

Table 3

COMPARISON OF THE OPTIMUM MOISTURE AND THE BEST WORKABLE MOISTURE CONTENT OF SANDS FOR DIFFERENT CLASSES OF WORK

			Optimum Moisture	
Section	A. F. A. Grade No.	Best Workable Moisture Content	Tensile Strength	Permeability
¼–½	2D	6.0–7.0	4.0	5.0
½–1	3E	6.5–7.3	4.0	5.0
Green Core Sand	4E	7.2–7.8	5.0	6.0

It is not always practical, as illustrated in Table 3, to work a sand at its optimum moisture content. It will also be noted from Table 1 that the optimum moisture content results in a very low dry strength value.

Grade Test

For each class of castings made there is a definite surface requirement and this is closely associated with the grade test. The new sands used for making up the heaps must be of such grain size that when added to the heaps will keep the sand in a condition to produce the surface desired. A thorough investigation of the various grades of new sand must be made for this purpose. The A. F. A. method is used for the grade test determination and a detailed description may be found in the tentatively adopted methods of tests of the Joint Committee on Molding Sand Research.[4]

[4] *Tentative Grading Classification for Foundry Sands*, Trans. A. F. A., Vol. 35, pp. 193-197 (1927).

The grade test regulates to some extent the workable moisture limits of a sand. The coarser grades of sand require a slightly higher moisture content, for example, the best results from a sand of A. F. A. grade test 1 was obtained between 6.0 and 6.5 per cent moisture, while a sand of A. F. A. grade test 4 required moisture limits between 7.2 and 7.8 per cent, both sands having the same clay content.

Durability Test

Molding sand must retain sufficient life when in use and not burn out too quickly, otherwise there is a considerable waste in the foundry. The lack of durability is due to the loss of bond or strength by dehydration of the clay, and as a general rule, sands containing the hydrated iron oxide bond while very strong have a tendency to burn out much more readily than those possessing the hydrated aluminum silicate bond.

The continuous pouring method in our opinion is at the present time the most practical method for determining the life of molding sand. For a test of this kind sand equivalent to a day's work should be put on the floor and used continuously for making a standard type of coreless casting. The sand should be tested regularly throughout its life and should be used until it is no longer moldable. Two sands, A. F. A. grade number 1E, representative of different districts, are indicated in Table 4.

Table 4

CONTINUOUS CASTING METHOD FOR DURABILITY DETERMINATION ON REPRESENTATIVE SANDS FROM DIFFERENT DISTRICTS. BOTH SANDS ARE OF A. F. A. GRADE 1E

Times Sand Was Used	Sand A. F. A. *1E Tensile Strength lbs./in.^{2}	Permeability	Sand A. F. A. †1E Tensile Strength lbs./in.^{2}	Permeability
Original Sand	0.540	22.7	0.362	14.4
5	0.460	22.0	0.350	14.8
10	0.404	22.7	0.335	13.9
15	0.351	23.4	0.317	15.0
20	0.283	22.8	0.295	14.5
25	0.272	23.2	0.297	15.8
28	0.257	22.9	0.297	16.4
31	....	...	0.278	18.6
36	....	...	0.271	17.5
40	....	...	0.261	16.8
42	....	...	0.253	16.1

The durability of molding sand as determined by this method is accurate but care must be taken in testing.

The need for a laboratory life test is readily apparent, and an investigation was begun on one similar to that proposed by Dietert.[5] For this test the sand was placed in a covered cast iron container to a depth of one-half inch and heated in a furnace at 600 degrees Fahr. for two hours. The reserve strength and percentage loss in bond was determined and later repeated after heating to 1200 degrees Fahr. The temperature was controlled with a pyrometer to within ± 15 degrees Fahr. Results of this test are indicated in Table 5, the sands marked *1E and †1E are those indicated in Table 4.

Table 5

DIETERT LABORATORY TEST FOR DURABILITY ON NATURAL SANDS. RESULTS ARE GIVEN IN POUNDS PER SQUARE INCH TENSILE STRENGTH

A. F. A. Grade No.	Original Strength	Strength After Heating to 600 Deg. F.	Loss in Strength per Cent	Strength After Heating to 1200 Deg. F.	Loss in Strength per Cent
*1E	0.540	0.295	45.4	0.160	70.3
†1E	0.367	0.330	10.1	0.190	48.2
1E	0.405	0.310	23.7	0.202	50.6
2D	0.366	0.290	20.8	0.220	39.9
3F	0.549	0.472	14.0	0.152	72.2
4E	0.359	0.295	17.8	0.158	56.0
4F	0.643	0.280	56.4	0.134	79.3

*Optimum Moisture Content (Tensile Strength).
†Optimum Moisture Content (Permeability).

The two heats, 600 degrees Fahr. and 1200 degrees Fahr., seem to give a better indication of durability than just the 600 degrees Fahr. The percentage loss in strength does not determine accurately the life of the sand, for it does not give proper weight to the reserve strength. It is apparently necessary in this particular test to give much consideration to the reserve strength as well as the percentage loss in strength.

This method was probably only intended to indicate in a general way the durability of molding sands, but it is hoped that a laboratory method will be devised which will determine accurately the durability of molding sands.

[5] *Commercial Application of Molding Sand Testing*, Trans. A. F. A., Vol. 32, pt. 2, pp. 25-26 (1924).

The durability of sand is important from a standpoint of economy, but under some conditions the amount of new sand, necessarily added to replace the loss of sand, is sufficient to keep up the quality of the sand, and in this case the durability of the natural sand is only of slight interest, the important factor to be considered here is the fusion point.

Relative Fusion Test

The fusion point of molding sand is associated with cleaning room costs and the quality of the surface produced. A sand possessing a low fusion point has a tendency to adhere to the casting, especially in the corners where its cost of removal is sometimes very large. While sand adhering in the corners of a casting does not seem to be very noticeable as it comes from the tumbling room, it may be indicated in subsequent finishing operations, especially where the surface is japanned, so that it is essential to either properly clean the casting, which entails a greater expense, or use a sand of a relatively high fusion point.

A test was developed which determines in a very general way the relative fusion point of molding sands and which has been found to be consistent with practical results. For this test the sand should be tempered to 6.0 per cent and pressed into a small die, one inch in diameter and one-half inch high. This disc of sand after being removed from the die is placed on a nichrome plate in a furnace at 2350 degrees Fahr. for 10 minutes. After cooling the disc is fractured and observed under a magnifying glass to determine its degree of fusion. According to the results of this test, molding sands may be divided into four general classes; class No. 1 sands which sinter very badly, turning black; class No. 2 sands which sinter slightly but whose individual grains cannot be identified; class No. 3 sands whose individual grains can easily be identified but still adhere to each other; class No. 4 sands whose grains fall apart when cooled.

It has been our experience that sand possessing a low fusion point has a tendency to produce an inferior surface.

Microscopic Examination

Microscopic examination should be made on the grains of

green sand after the deflocculation of the clay to determine the shape of the grain and if possible the quality and quantity of any foreign matter. Sand grains may be divided according to their grain shape into four classes, angular, sub-angular, rounded and spherical.

Routine Testing

The A. F. A. sand tests are applicable to all foundries, but each foundry has its own particular requirements and a close study of these tests will determine a standard for each class of castings which should be maintained within close limits by routine testing.

Natural sands submitted for trial are subjected to the following tests in order to determine their suitability:

1: Tensile strength test.
2: Permeability test.
3: Grade test.
4: Dry strength test.
5: Durability test.
6: Relative fusion test.
7: Microscopic examination.

In order to provide a uniform product it is advisable to test each carload of sand delivered. If large variations are found in the sand it is difficult to properly control the sand heaps, and this is especially true in a mechanical system where the sand is added systematically. The moisture content of green sand is usually much greater as received than when it is used in practice, so, in order to properly test the sand, it should be dried at 105 to 110 degrees Cent. for one hour, then retempered to the workable moisture content or spread out to air dry to this moisture content, mixed and tested.

For routine checking of sand shipments the following physical properties are determined on each carload lot:

1: Tensile strength.
2: Permeability.
3: Grade.

After obtaining a suitable sand it is essential to keep the heaps within predetermined limits, thereby giving the molder a uniform sand. In floor molding these tests need only be made

once per day, but with a mechanical handling system they should be made more frequently.

The tests used more than any others for controlling the heap and facing sand are as follows:

1: Tensile strength test.
2: Permeability test.
3: Moisture test.

It is of interest to note that it is possible to determine these three tests in not more than eight minutes, also that both tensile strength and permeability tests are determined on the same specimen.

The contamination of the heaps by core sand drippings, etc., are indicated by the following tests determined semi-monthly:

1: Dry sand strength.
2: Grade test.

Table 6 indicates testing limits which have been found to give very good results in our light castings foundry.

Table 6

TESTING LIMITS FOR VARIOUS SECTIONS WHEN USING A SQUEEZER TYPE MACHINE

Section	Sand	Moisture	Tensile Strength lbs./in.^{2}	Permeability
1/8–1/2	Facing	6.0–6.5	0.350–0.420	18–24
	Heap	6.5–7.0	0.290–0.350	19–26
1/2–1	Facing	6.5–7.0	0.660–0.770	30–40
	Heap	6.8–7.3	0.420–0.490	34–44
Green Core Sand		7.2–7.8	1.150–1.400	55–75

Sand testing properly applied will decrease foundry losses, produce a better surface quality and will effect an economy in the use of sand. The knowledge obtained from sand testing has greatly facilitated our work and has opened a wide field for investigation.

Mulling

An investigation of the mulling action of molding sands in a mechanical system has given some very interesting information.

The effect of mulling in a standard type muller and passing through a centrifugal aerator is illustrated in the Chart of Fig. 3. The moisture content on these sands are as follows: A—6.6 per cent; B—6.3 per cent; C—7.2 per cent.

In foundry practice it is not usually practical to mull the sand for any great length of time, so that in the above charts mulling was indicated only for a 15 minute period.

Mulling tends to bring out the latent strength value of the sand to a marked extent, depending upon the time mulled and the

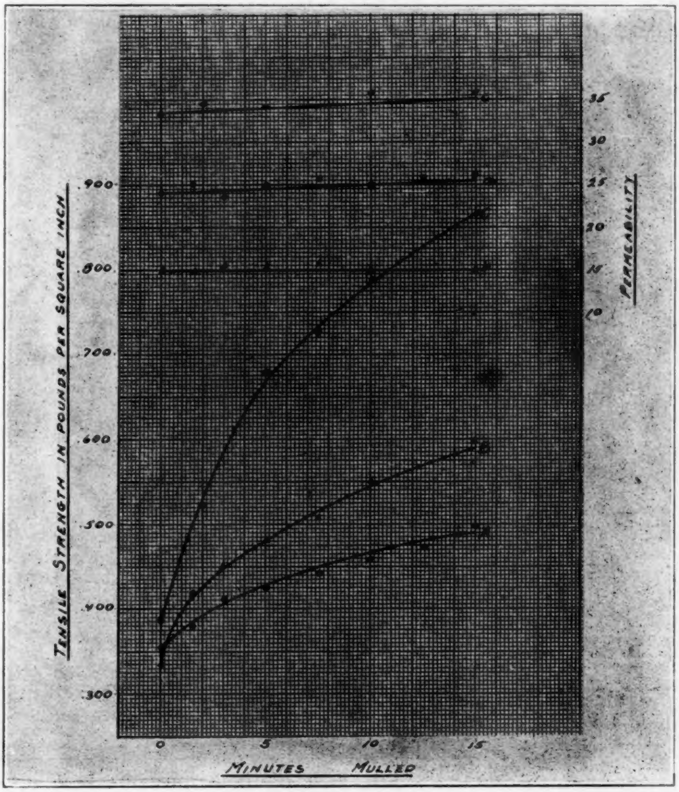

FIG. 3—EFFECT OF MULLING AND AERATION ON THE TENSILE STRENGTH AND PERMEABILITY OF MOLDING SANDS. A, HEAP SAND A. F. A. GRADE 2D; B, NATURAL SAND A. F. A. GRADE 1D; C, HEAP SAND A. F. A. GRADE 3E.

clay content. There was no apparent effect on the permeability or the grade test after passing through the aerator.

The results given above led us to determine the effect of heavier rolls in mulling sands. Rolls weighing approximately one and two tons were compared under identical conditions for a 10

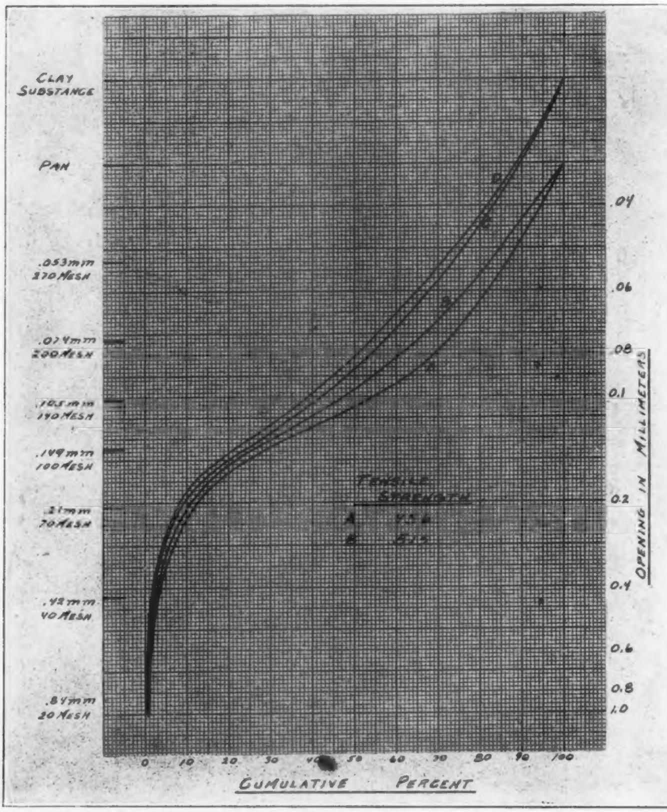

FIG. 4—EFFECT PRODUCED BY INCREASING THE WEIGHT OF THE ROLLS IN THE MULLER. A, HEAP SAND MULLED TEN MINUTES WITH ROLLS WEIGHING ONE TON, DRY TEST; B, HEAP SAND MULLED TEN MINUTES WITH ROLLS WEIGHING TWO TONS, DRY TEST; C, GRADE TEST OF (A) DEFLOCCULATED; D, GRADE TEST OF (B) DEFLOCCULATED

minute mulling period, and the results indicated in the chart of Fig. 4. The sand used in this test was passed through a centrifugal aerator and is that sand indicated as A in Fig. 3. The heavier rolls also had a 40 per cent larger face surface than the lighter rolls.

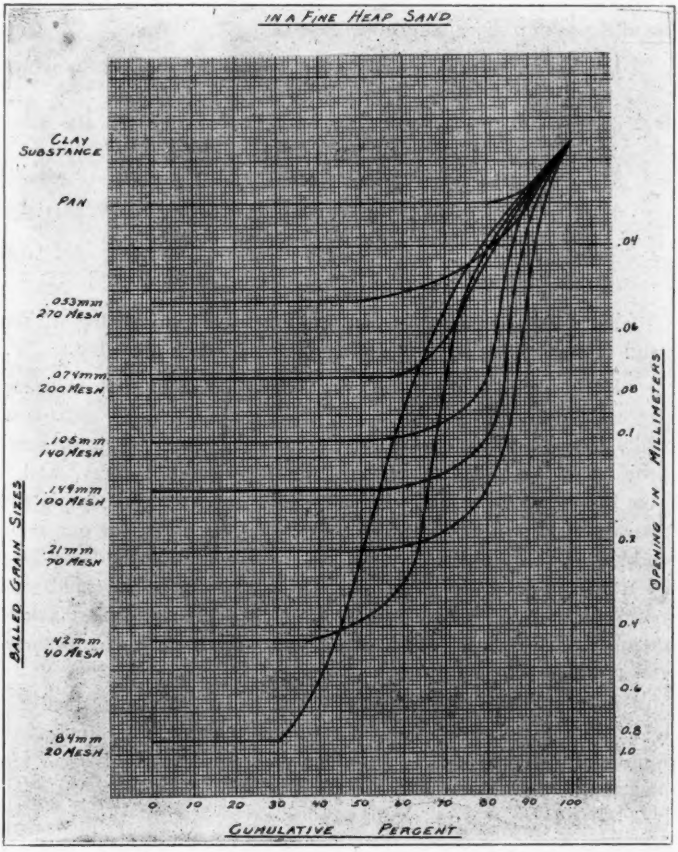

FIG. 5—GRAIN SIZE COMPOSITION OF THE BALLED GRAINS IN A FINE HEAP SAND

The heavier rolls give a better distribution of clay as indicated by an increase in strength and also have a greater tendency to break down the grain clusters.

The small difference in the deflocculated grade tests probably results from a slight breaking down of the sand grains due to the heavier rolls.

The advantages obtained from a muller in a mechanical handling system may be grouped as follows:

1: To uniformly distribute the green sand and the moisture in the shortest possible time.

2: To obtain a good distribution of clay over the sand grains, depending upon the time mulled.

3: To increase the tensile strength of the sand.

4: To break down the clusters or balled sand particles which arise from mechanical handling.

Balling Action of Fine Molding Sand

Sand deteriorates considerably due to the coarsening of the sand from the balling of the fine grain particles and clay.

If the sand is dried and then sieved without deflocculating and washing away the clay a determination is obtained as to how badly the clay is balled. Figs. 5 and 6 illustrate the grain composition of the balled grains in a fine heap sand, Tables 7 and 8 give the tabulated results of this test. In preparing a sample for test the sand was dried at 105 to 110 degrees Cent. for one hour and sieved according to the Tentatively Adopted Methods of Test of the Committee on Molding Sand Research.[6] The sand was removed, more added and the operation repeated until a sufficient quantity was obtained for a deflocculated grade test of the material retained on each sieve.

A comparison of the grain size of balled sand in the natural and deflocculated condition together with the same sand after mulling for 10 minutes in a muller whose rolls weighed one ton and aerated is illustrated in the chart of Fig. 7.

There is practically no breaking down of the sand grains. The balling action of a sand may be described as the formation of

[6] *Fineness Test*, Trans. A. F. A., Vol. 31, pp. 722-726 (1923).

hard rounded pellets of fine sand and clay. These pellets naturally increase the essential grain size of the sand and the effect is proportional to the amount of sand and clay that has been balled.

Sand which is moistened and remains for at least several hours before cutting over, allowing the moisture to distribute uniformly, as in floor molding, will ball up very slowly. In floor

Table 7

GRAIN SIZE COMPOSITION OF THE BALLED GRAINS IN A FINE HEAP SAND

Mesh	20 Mesh	40 Mesh	70 Mesh	100 Mesh	140 Mesh	200 Mesh	270 Mesh	Pan
6	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...
20	30.8	...	...	...	...	...	...	...
40	13.8	36.9	...	...	...	...	...	...
70	5.6	26.5	44.0	...	...	...	...	...
100	3.4	2.3	36.0	52.7	...	...	...	...
140	6.0	2.9	4.5	26.9	50.9	...	...	...
200	7.4	3.4	2.5	5.0	29.6	56.8	...	...
270	3.0	1.9	2.5	1.5	3.1	18.1	47.9	...
Pan	16.0	11.7	4.5	6.2	5.7	13.9	42.6	80.6
Clay Substance	14.0	14.4	6.0	7.7	10.7	11.2	9.5	19.4

Table 8

GRAIN SIZE COMPOSITION OF THE BALLED GRAINS IN A FINE HEAP SAND MULLED FOR 10 MINUTES

Mesh	20 Mesh	40 Mesh	70 Mesh	100 Mesh	140 Mesh	200 Mesh	270 Mesh	Pan
6	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...
20	61.8	...	...	...	...	...	...	...
40	10.0	68.9	...	...	...	...	...	...
70	1.6	17.3	66.6	...	...	...	...	...
100	2.2	0.8	23.2	67.3	...	...	...	...
140	2.1	0.5	0.4	19.5	51.1	...	...	...
200	2.3	0.9	0.3	1.3	28.2	56.2	...	...
270	1.3	0.4	0.2	0.3	2.3	11.6	46.9	...
Pan	8.7	4.3	1.7	2.2	6.3	18.6	38.9	78.9
Clay Substance	10.0	6.9	7.6	9.4	12.1	13.6	14.2	21.1

molding work the sand is moistened after the floor is shaken out and remains this way for a number of hours before it is handled. It is generally known that sand becomes coarser through handling, and this effect is of much greater magnitude with mechanical handling.

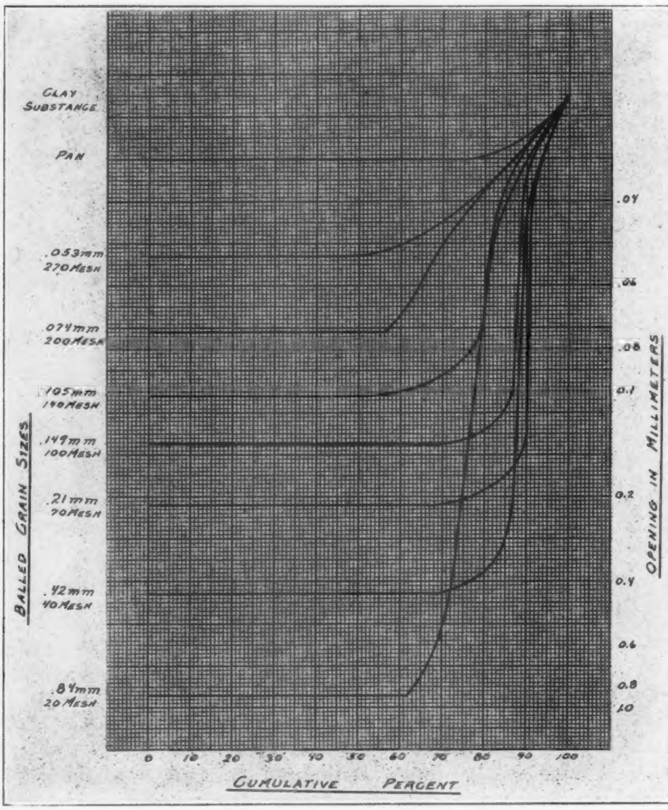

FIG. 6—GRAIN SIZE COMPOSITION OF THE BALLED GRAINS IN A FINE HEAP SAND AFTER MULLING TEN MINUTES

We believe from observations in the foundry that the balling effect of sand is due to the movement of the sand containing a critical moisture content together with an uneven distribution of moisture and that the balling effect is increased by an excess clay content.

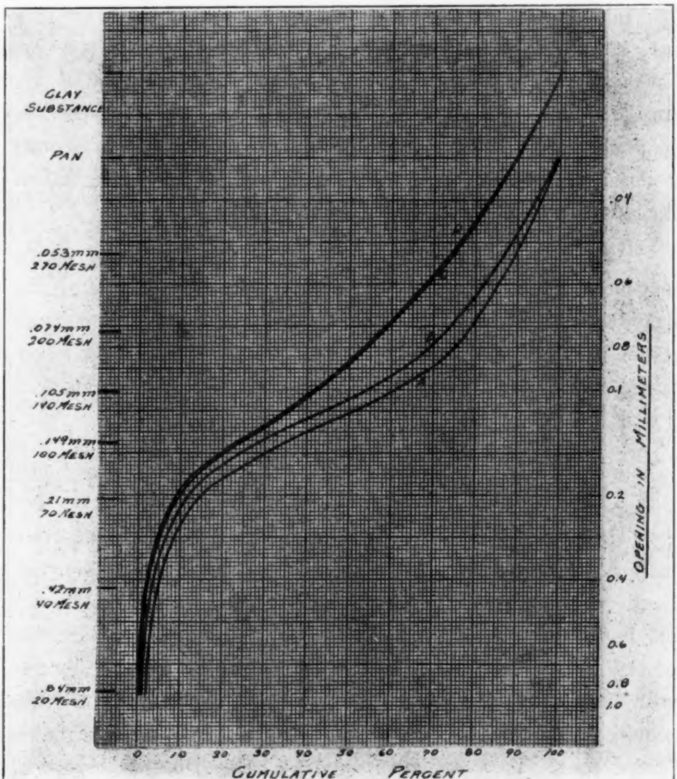

FIG. 7—GRAIN SIZE OF BALLED SAND IN THE NATURAL AND THE DEFLOCCULATED CONDITIONS. A, HEAP SAND, DRY TEST; B, HEAP SAND MULLED TEN MINUTES, DRY TEST; C, GRADE TEST OF (A) DEFLOCCULATED; D, GRADE TEST OF (B) DEFLOCCULATED

A badly balled up sand is always a source of trouble in the foundry, but may be counteracted by the addition of a fine sand, a lower clay content sand, mulling, improvement in handling conditions, or a combination of these.

Moisture Control

In foundries making heavy castings the moisture content may vary considerably, but it plays a very important part in our particular case affecting both the discount and surface quality of our small castings and we must aim to keep it as uniform as possible at all times. On the examination of daily moisture records quite a variation was noted and means were devised to reduce this as far as possible.

A water meter attached to the muller has been tried over a long period and has given very good results. By the use of this meter together with constant checking by the laboratory moisture tester, previously described, a very uniform facing sand is obtained which has considerably reduced our moisture variation.

This water meter installation is shown in Fig. 8.

Conservation and Reclamation

The tests and investigations previously described have eventually led us to the problem of sand conservation and reclamation. Sand reclamation is not new and for many years foundrymen making iron castings have attempted to save sand by the addition of clay in some form or another to their heaps, but generally met with little success, particularly where a high grade surface was required. Another serious factor which has in former years retarded conservation and reclamation was due to the absence of methods by which the physical properties of the heaps could accurately be determined.

There are a variety of methods which may be employed in

conserving and reclaiming sand and the adoption of any of these will depend on the type and lay-out of the foundry, also on whether the fine sand and silt is harmful for the sand requirements. Where an increased permeability is essential it is necessary to remove this silt but the latter may be utilized where a fine sand for small castings is desired.

We, at first, attempted to conserve the refuse sand from the rattlers which consisted of approximately 4 per cent iron dust by converting this iron dust into ferric oxide by an "ageing" process, the sand later being made into a substitute for natural sand by mulling with the proper addition of clay. After a long period of use the surface quality began to deteriorate, at the same time the fusion point was lower due to the very gradual accumulation of iron oxide, and for this reason its use was discontinued.

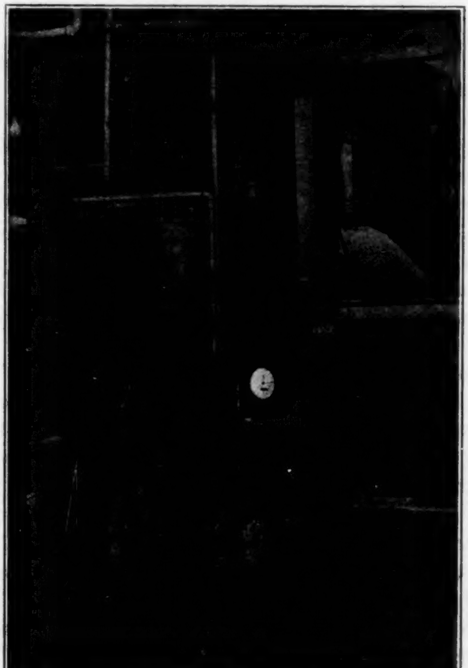

FIG. 8—WATER METER FOR MOISTURE CONTROL

Later we successfully reclaimed the burnt sand which clings to the sprues and gates of the casting and which is not contaminated with iron. We use essentially two grades of sand and the burnt sand collected is mixed, so that in order to obtain sands which are satisfactory for our purpose it is necessary to make a separation into two grades, a coarse grade used for medium light sections, and a fine grade used for very light sections. The sand is separated by means of a Hummer vibrating screen which is arranged to give the desired products. The material retained on the upper screen, consisting of small iron particles and large burnt sand clusters, is discarded, the material retained on the lower section, A. F. A. grade No. 3, is used for the medium light sections where permeability is required, and the material passing through the second section, A. F. A. grade No. 1, is used for very light castings. Water is sprinkled into enclosed receiving bins so that no dust will be created.

Each grade of sand is mulled from 5 to 8 minutes with a definite amount of clay, the mulling being continued only long enough to get a good distribution, and the sand is then passed through a centrifugal aerating machine and is ready for use. A dry pulverized clay ground to a 140 mesh is used for this purpose. We find this sand to be a satisfactory substitute for natural sand, and that it can be used alone or mixed with other sands.

Special attention should be given to the quantity of clay and its distribution, for many failures may be attributed to a faulty clay content. For best results the clay should be kept as low as possible consistent with green strength values.

A synthetic sand is used for making green sand cores where a very strong sand with a relatively high permeability is essential. In making this sand, sea sand, burnt core sand, and clay are used, the mixture being mulled and aerated in the manner previously described.

We believe that sand testing and sand control is an advantage to the foundry, specifically in reducing foundry discount and improving the surface quality and indirectly in opening a field of investigation which results in economy in the use of sand and a general improvement due to a better knowledge of the properties and requirements of foundry sands.

An Automatic Precision Strength Test for Sand[1]

By G. G. Brown,[2] Ann Arbor, Mich., and C. C. DeWitt,[3] Houghton, Mich.

In the course of work being done for the Michigan Geological Survey on the sands of Michigan and on the probable cause of bond in molding sand, it became imperative that a simple automatic device be used for determining the strength of sand, that would be capable of precise results, as it was necessary to measure even slight differences in the compressive strength of different sands.

The work involved the investigation of the effect of colloidal matter on the strength of sand. The dye adsorption test as a criterion of mechanical strength could not be used, for the dye adsorption test indicates the relative amount of a given quality of colloid present. Obviously, such a test gives no direct measure of the compressive, tensile or transverse strength of the sand. In fact, the dye-adsorption seems to depend upon a true chemical equilibrium.[5] In general, considerable difference of opinion is expressed by various investigators on the relative values of different physical tests used for indicating the strength of the sands. For this reason, a number of preliminary tests were made to in-

[1] Part of a thesis submitted by C. C. DeWitt in partial fulfillment of the requirement for the Degree of Doctor of Philosophy in the Graduate School, University of Michigan, Ann Arbor. Published by permission of R. A. Smith, Michigan State Geologist.

[2] Professor of Chemical Engineering, University of Michigan.

[3] Professor of Chemistry, Michigan College of Mining and Technology, Houghton, Michigan.

[4] Nevin, Transactions of the American Foundrymen's Association, Vol. XXXIII, p. 763 (1925).

[5] Gordon, *Colloid Symposium*, Chemical Catalogue Company, p. 114 (1924).

dicate the degree of precision that might be expected in using the different methods that have been described. Adams[6] has made a careful survey of the different types of testing machines that have been described up to 1926.

Preliminary work clearly indicated that the cohesiveness test recommended by the committee on molding sands, of the American Foundrymen's Association, would not prove satisfactory because it requires a relatively large amount of sand and gives an accuracy not exceeding the limit of plus or minus 5 per cent. The cohesiveness test is also difficult to analyze as the sample breaks under a combination of tensile and compressive forces, and the unit compressive and tensile stresses will not be equal unless the cross-sectional area above and below the neutral axis is the same.[7]

The compression tests of Hansen[8] and of Dietert[9] were carefully considered and were found to be satisfactory except for the limit of accuracy in these devices. The dimensions of the cylinder used by Hansen are open to criticism, as a cylinder of the same diameter as height is very apt to break in the faces. With the ideal or homogeneous short cylinder breaking under compression, the angle of fracture would be 45 degrees with the rounded face of the cylinder, assuming that all the samples of sand have the same unit tensile and compressive strength. Since this is not strictly true, the angle varies for different materials. As shown by Boyd, "failure takes place along a plane which makes an angle of 45 degrees plus one-half the angle of friction with the plane normal to the compressive force." With samples breaking on the face, it is evident that the compressive load is not supported by the entire cross-sectional area, but only by a part thereof. Dietert's sample takes into consideration the problem mentioned and eliminates this error, but his machine disregards the need for uniform loading, which is now recognized to be an important variable.[10] An attempt was made to drive Dietert's machine by a motor in order to give approximately the same rate of loading for different

[6] Adams, Transactions of the American Foundrymen's Association, Vol. XXXIV, p. 404.

[7] Boyd, *Strength of Materials*, McGraw-Hill Book Company, New York, p. 114 (1917).

[8] Transactions of the American Foundrymen's Association, Vol. XXXII, p. 57 (1924).

[9] Transactions of the American Foundrymen's Association, Vol. XXXII, p. 24 (1924).

[10] Transactions of the American Foundrymen's Association, Vol. XXXIV, p. 521 (1926).

samples. The results were unsatisfactory because it is important to have a uniform rate of loading throughout the entire compression test, and this could not be obtained due to the air contained in the pressure gauge.

The tensile testing apparatus developed by Grubb[11] is simple and should be subject to as accurate a determination as any compressive test.

The testing machine developed by Adams[12] loads the sample at a peculiar harmonic rate due to the moving fulcrum. The use of the pantographic method of applying the load to the sand sample involves the application of lateral forces when the compressive load is applied. For these reasons it seems to contain too many sources of error for our purpose.

As the compressive test seemed to afford one of the best known tests of strength, a machine for testing the bond strength of molding sands by failure in compression was constructed with the following considerations in mind:

1. No initial loading of sample,
2. Freedom from impact forces,
3. Constant rate of loading,
4. Automatic operation, stopping, and indication of breaking load,
5. Accurate and sensitive to less than one gram.

Construction

The machine assembled is shown, diagramatically in Fig. 1, and in Fig. 2. The principle upon which the machine is built is that of a simply supported beam, between whose supports a weight is caused to travel at a constant rate.

By counterpoising such a beam and weight on one of the supports and making the weight travel an appropriate distance before any load is applied on the other support, no initial load is put upon the sample. The sample is placed almost in contact with the piston face applying the pressure, and as the sensitivity of the machine is of the order of one gram the initial load or shock of the impact force is negligible. As soon as the moving weight

[11] Transactions of the American Foundrymen's Association, Vol. XXXIV, p. 522 (1926).
[12] Transactions of the American Foundrymen's Association, Vol. 34, p. 448 (1926).

crosses the point where the load begins to be applied to the sample the piston comes in contact with the sample and the machine becomes a beam simply supported at its two ends. If the weight is driven at a constant rate, the load increases at a constant rate. This is accomplished by an electric motor through a reduction gear and chain drive. The motor drive aids in eliminating the personal factor. The rate of loading is determined by the use of sprockets of various diameters and by changing the weight carried by the traveler.

As the weight (A) travels along the beam (C), there comes a time when the sample begins to give way, finally to break. To be able to record the pressure which caused a certain amount of deformation is easily done by adjusting the electrical contact (T) at the end of the beam. This electrical contact closes the circuit which operates a ratchet dog (J), and relay, not shown, in the rear of solenoid (G), which in turn operates an iron clad solenoid (G) the function of which is to pull away one face of friction clutch (H). By means of this mechanism the screw (B) propelling the weight (A) is made to stop when the sample breaks.

When the sample breaks and while the sample is being deformed, there is a slight shortening of the beam. By design the total shortening is very small. It has been found that most samples broke before being deformed more than two-tenths of an inch. The effective length of the beam used was 25 inches so that the total deflection of the beam before the sample broke is less than ½ of one degree. The total change in effective weight of the traveler at any time over any distance traveled would be about one part in a hundred thousand, far within any reasonable limit of error. This error, although negligible, can be almost wholly overcome by allowing the initial position of the beam to be one-half the distance of the probable deflection above the horizontal. This precaution was taken.

The most interesting part of the apparatus, and certainly the most important part as regards the accuracy of the machine as a whole, is the manner in which the pressure is transmitted from the beam to the sample under the piston. This application of pressure is made by a rolling point contact (M) and a vertical ball bearing race. The piston (L) is of hardened tool steel ⅝" in diameter fluted with six equi-spaced lengthwise ball races. The balls ride

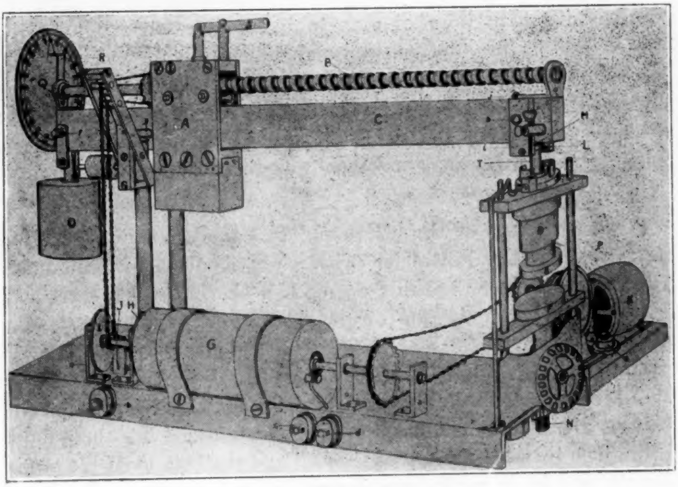

FIG. 1

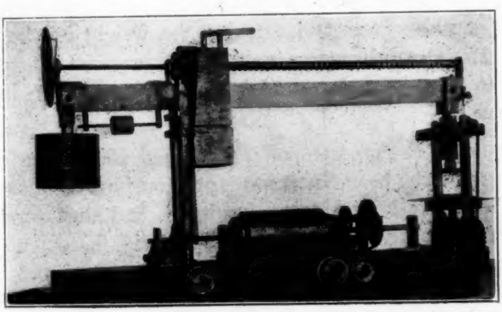

FIG. 2

against the fluted piston (L) and wall of the hardened internally ground bushing (D), their clearance being less than three ten-thousandths of an inch. Two sets of balls supported at intervals of two and a half inches along the fluted piston rod keep the piston rod in line. A hole through the piston rod near the top provides a means of suspending the piston and piston rod on the knife edges at the end of the beam. The function of these knife edges is to keep the saddle in its proper place, making the piston, piston rod, ball bearings and their supports a part of the counter-poised beam.

Over the top of the piston rod (L) there is slipped a brass ferrule, the internal diameter of which is about half a thousandth of an inch greater than that on the ball bearing which rests in a ground groove in the top of the piston rod parallel to the direction of the beam and exactly at right angles to the hole from which the saddle suspension is pinned to the piston rod. By means of screws at the top of the saddle, the hardened knife edge sockets are adjusted so that there is a clearance of one-thousandth of an inch between the top of the ball and the bottom of the beam. As the weight is applied the beam comes down on the hardened steel ball, and as the beam tends to shorten or lengthen the beam rolls over the top of the ball. The side thrust caused by such a motion can be no more than the amount of the horizontal component of rolling friction of a hardened steel ball between two hardened steel surfaces and carrying the weight of the load impressed on the sand sample so that the pressure is transmitted directly to the piston face and is the same at any point on the piston face.

The beam is supported on a hardened steel knife edge (g) which rests on the heads of screws, previously filed out to receive the 60 degree knife edge, case hardened, and then screwed into the top of the supports. The knife edges (f, g, h) extend through the beam and are fastened by means of set screws which turn into little cavities in the round shanks of the knife edges thus preventing their turning. The pivotal support is further reinforced by having the hardened end of the knife edge rest against a small steel ball bearing which is appropriately caged so as to give a rolling point contact to the end of the knife edge as the beam tips,

and to take any end thrust that might be developed by the chain drive of the screw which propels the weight.

The traveling weight (A), and screw (C), very much resemble those of the regulation testing machine, except that the screw is driven by a chain going over a sprocket, located at the exact center of the pivotal knife edge, from a counter shaft on the base of the apparatus. The weight is propelled by a single tooth which projects into the screw thread, being held there by a coiled spring. The tooth may be raised by means of a lever (S), allowing the weight to be returned to the starting position.

The screw (B) is machined from ¾" cold rolled steel and has two threads per inch. It is mounted by means of three small ball bearings, one of them a thrust bearing. These bearings (a) are in turn mounted in three holders made of angle iron appropriately sawed and drilled for containing the ball bearings and for fastening to the top of the beam.

The relay coils and the dog electro magnet are connected in parallel. One side of this circuit is grounded to the machine, the other is led to the battery line switch and up through the copper tube at the corner of the base to the mercury cup binding post. The battery leads are connected to one pole of the switch and to the machine base.

The 110 volt D. C. line is connected through the relay contact points to the solenoid winding and the switch (C) which is on the side of the machine. Across the relay contact points a snap switch (C) is connected. This switch breaks the solenoid current thus preventing undue burning of the relay points due to arcing caused by induced currents.

The motor is controlled by a snap switch (e) in one side of the 110 A. C. volt current supply line.

Further details of construction need not be given here. Modifications and exact dimensions are not essential to its proper operation, and may be made to suit conditions of use.

Operation

The traveling weight is pushed back, the counter poise weight adjusted by means of lead shot poured into its centrally cored hole, the battery current is turned on, the 110 Volt D. C. switch

is closed and the relay contact switch is closed which brings the face plate of the clutch back with a sharp click compressing the spring on the shaft. The motor switch is turned on. One face of the friction clutch is now revolving. The relay contact switch is opened. The spring forces the plunger and clutch face plate forward against the still face plate of the jack shaft clutch. The jack shaft is revolving. The chain slowly trundles over the sprockets, the tooth of the traveling weight jumps onto the thread, the screw revolves, the weight moves out along the beam which suddenly dips downward. As soon as the electrical contact is made by (T) at the mercury cup, the electro-magnetic dog stops the jack shaft and the functioning of the relay causes the driving face of the clutch to be pulled back. Switch (d) is turned on to prevent relay contact points from arcing due to induced currents otherwise produced by lifting the beam and breaking the contact between (F) and the mercury cup. When the machine is to be stopped the switches are turned off in the following order: e, b, c, d.

Calibration

A light metal saddle and a half inch steel ball is counter poised on a balance for large loads sensitive to ¼ gram. The saddle is made to swing from the balance under the upper crushing face. A ½" steel ball is placed between the saddle face and the upper crushing face. The position of the saddle face and ball are adjusted by means of the screws at the ends of the saddle so that the light can just be seen between the metal ball and the crushing face when the beam is in the "up" position. A weight is placed on the opposite balance pan; the machine is started and allowed to trip the balance, stopping the screw, traveling weight, etc. The position of the weight on the beam is marked temporarily and the reading on the disk at the end of the screw is noted. The operation is repeated several times for each point obtained; the weights placed on the balance pan being recorded, the disk readings noted and the beam marked for each position of the weight. It was found that scarcely any variation in the loading could be observed, that a divider used to measure the distance between the marks on the beam caused by like increments of weight on the balance pan needed no adjustment. The weight of the traveler was so adjusted that the reading was ⅔ of the actual load; that

is, the reading multiplied by 1.50 gives the actual load in grams. After several months of more or less continuous use the calibration of the machine had not perceptibly changed.

Rammer

The rammer used in preparing specimens for compression tests is an adaptation of that described by Dietert (Fig. 3).[13] It consists of a steel rod supported by a steel frame. The guides of this steel frame are drilled to give the steel rod a sliding fit. A cast iron head weighing exactly seven pounds slides on the rod. Stops pinned to the steel rod regulate the movement of this head to 1.95 inches. The sand is placed in a cast iron cylindrical mold 1⅛" internal diameter on a steel pedestal.

The frame supporting the steel rod is secured to a piece of cast iron 21" x 18" x 3", both flat sides of which are smoothly machined. An indicator consisting of a brass frame on which is pivoted a light beam carrying a knife edge one inch from the pivoted end as shown on the top of the rammer (Fig. 3) is used to measure accurately the height of the rammed sample.

The scale at the end of the indicator beam is calibrated from 1.75" to 2.20" by hundredths of inches using Johannsen gauge blocks.

Bond Strength Testing

The cast iron collar of the pedestal of the ramming device was adjusted so that the cylinder resting on it would contain enough sand to form a sample about two inches high by 1⅛" diameter (about 38 to 44 grams). The sand was transferred to the forming cylinder on the pedestal and the weight of the steel guide rod and rammer head allowed to rest momentarily on the top of the sand while the weight was being raised by hand to the upper stop pin. As the weight came in contact with the upper pin it was allowed to fall freely.

This was done three times for each sample, care was taken that during the ramming operation the face of the rammer was always in contact with the face of the sample.

Directly after ramming, with the rammer face still resting on

[13] Transactions of the American Foundrymen's Association, Vol. XXXIII, p. 721 (1925).

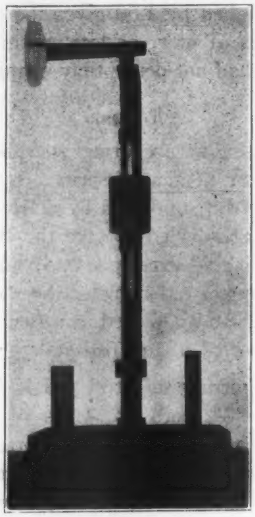

FIG. 3

the sample, the beam of the indicator was swung into position so that the knife edge bearing came in contact with the top of the guide rod and the height of the sample read to the nearest .005" from the scale and recorded.

The sample was rammed from one end only. The reason for this was to eliminate any possibility of error in preparation, that might be due to any small misalignment of the sand cylinder top and bottom rammer which might occur if the sand were rammed from both ends causing the three to bind and stick or otherwise absorb the kinetic energy which should have gone into compressing the sand sample to the required dimensions. Preliminary work showed this precaution to be a refinement necessary for consistent results. Reversing the ends of the samples rammed from one end only in the testing machine showed no difference in breaking strength.

The samples were stripped from the cylindrical mold by lifting the mold off the pedestal and pressing the sample out of the mold on a long steel pedestal or column of like diameter. The

sample was grasped between the thumb and forefingers and the excess sand blown off each end.

The sample was then placed on the movable face plate (F) of the compression machine, Fig. 1. The motor having been started and switches (b, c, d, e) closed, the position of the sample was adjusted to bring it just into contact, with the upper surface (E) by means of the hand wheel raising the lowering (N). Switch (d) was snapped off setting the weight in motion. When the sample was broken the weight was automatically stopped indicating the breaking load by its position. The crushing plates were carefully wiped free of sand, and opened by turning the hand wheel. Some broken parts of the sample that fell were caught on a clean piece of paper placed below the front end of the machine; the sand which came in contact with nothing other than metal or paper or wooden table top was returned to an individual container provided for that particular sand.

The cylindrical ramming mold was carefully cleaned by drawing a clean cloth through it and any sand that might be near the pedestal or on it was removed after each determination. When a completed series of tests on one sample had been run any scattered sand on the machine and the table where the ramming had been done was carefully brushed up and returned to the container or preferably discarded.

Accuracy

The compressive strengths of sand samples prepared and tested in the manner described show a maximum deviation between extreme values of:

16.4 grams on samples of 683 grams average strength per sq. in. or 2.36 per cent,

9.75 grams on samples of 960 grams average strength per sq. in. or 1.01 per cent,

36.0 grams on samples of 2440 grams average strength per sq. in. or 1.46 per cent,

and a maximum deviation from the mean of five or six check determinations of:

9 grams on sample of 683 grams average strength per sq. in. or 0.9 per cent,

9 grams on sample of 960 grams average strength per sq. in. or 0.9 per cent,

23 grams on sample of 2440 grams average strength per sq. in. or 0.94 per cent.

Summary

A precision method of testing the compressive strength of molding sands with an accuracy of plus or minus one per cent has been described. The method includes an automatic testing machine capable of precise work which can be readily adapted for making tensile or transverse tests.

Although such accuracy is probably not necessary in industrial routine testing, it is frequently necessary to determine slight differences in careful research work. The machine was designed for this purpose and has proven entirely satisfactory in our research laboratories.

The Influence of Ferric Hydrogel in the Bond of Natural Molding Sands[1]

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Ann Arbor, Mich.

Abstract

This paper reports quantitative data showing the relation of colloidal ferric oxide absorbed on the sand grains and on the clay bonding material to the strength of bond in the molding sand, and the successful preparation of synthetic molding sand obtained in the course of work done on Michigan sands for the Michigan Geological Survey. The effect of colloidal iron oxide on the bond of molding sands has been determined by analytical methods on natural sands; and by synthetic methods successfully reproducing the bond of natural molding sand by the proper combination of clean unbonded sand or silica, kaolin, and ferric hydrosol.

1. *Introduction*

A molding sand has been defined by Littlefield[2] as any material which when moist can be formed into a mold from which usable metal casting may be made. This definition includes all combinations of sand and clay or other material, and it implies all desirable qualities that a molding sand must have, the two most important of which are bond, so that the mold may have sufficient strength to support the metal while being poured, and permeability to gases, so that the gases may readily escape, giving a sound casting free from blow holes.

The cause of permeability is reasonably well understood and satisfactory tests for this property have been developed, adopted, and are in constant use.

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[1] Part of a thesis submitted by C. C. DeWitt in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan. Published by permission of R. A. Smith, Michigan State Geologist.

[2] Littlefield, Bulletin No. 50 Illinois State Geo. Survey, p. 20 (1925).

.Of the actual cause of bond in molding sand very little definite information is available. It has been thought that the presence of iron oxide had something to do with the bond, [3, 4, 5, 6, 7] but there is also some evidence that is contradictory.[8, 9] Little agreement is found concerning the origin and condition of the iron oxide even among those who consider iron oxide important in giving bond to a sand.

Condit[8] states that the hydrated iron oxide films on sand and clay particles are formed by precipitation of iron salts from surface water. "Surface waters charged with organic acids readily dissolve iron. As these waters percolate downward the iron is precipitated between the sand grains. For this reason the grains of most molding sands are thickly coated with limonite."

In direct contrast to Condit's views, Gordon[10] accounts for the presence of colloidal gel coatings on silicate particles as formed by decomposition of the sand grains themselves.

Whitney[11] also considers that the soil colloids are derived from the sand particles which become hydrolyzed not by being precipitated from solution but by molecules of water bombarding the soil particles when they have reached a diameter of 0.0001 millimeter.

Boswell[4, 5, 6,] reports the beneficial effects of iron oxide as a binder in the British red sands as follows:

"The chief natural bonds in molding sands are ferric hydroxide and clay substance (silicate of alumina, fine micas, etc.). These, like many of the artificial bonds in common use, are colloidal bodies. The adsorptive power of clay, in the matter of both gases and solutions increases, according to Senfft, with the limonitic content. J. Van Bemelen found as long ago as 1878 that the amount of 'hydrate water' of ferric oxide was variable and accidental. When just dry at 15 degrees Cent. the com-

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[3] King and Schlichter, U. S. Geo. Survey, 19th Annual Report (1899).
[4] Boswell, Engineering, 108; 418-20, 464-66 (1916).
[5] Boswell, Foundry, 47; 593 (1919).
[6] Boswell, Trans. Am. Foundrymen's Assoc., 27; 305 (1918).
[7] Hanley and Simonds, Foundry, 48; 772-74 (1920).
[8] Condit, Trans. Am. Foundrymen's Assoc., 21; 21-27 (1912).
[9] Moldenke, *Principles of Iron Founding*, McGraw-Hill, New York (1917).
[10] Gordon, *Colloid Symposium*, Chemical Catalogue Book Co., p. 114 (1924).
[11] Whitney, Science, 54; 656 (1921).

pound is able to take up over six molecules of water per molecule of ferric oxide. One of the most marked characteristics of the best sands is their extraordinary power of taking up considerable quantities of water without really becoming wet. The following figures (Table 1) for example, are those of hydroscopic water (liberated at 110 degrees Cent.) contained in molding sands (some of them moist but none wet) as collected in the field.

Table 1

Sand	*Per Cent*	
Cornish Red	11.6	
Erith Strone	10.2	
Belgian Yellow	6.6	partly dried
Wolverhampton	13.5	
Kiddermaster	8.0	

"Another important desideratum of good molding sands, possibly connected with the colloidal character of the bond, is that they should not 'go dead,' that is, dehydrate too readily after metal has been cast in them. Iron oxide readily hydrates again, unlike clay which may be 'porcellanized' by heat.

"The distribution of the bond in naturally bonded sands is ideal. Each grain of quartz is coated with a thin pellicle of ferric hydroxide or ferruginous clay. Water skins cannot hold on to clean quartz, but each coated grain assumes the skin of water, which with its neighbors constitutes the enormously strong 'green bond' of the sand.

"It is noteworthy that in the West European sand the higher the percentage of ferric hydroxide the greater is the transverse strength in the sands. In the case of the sand from South Africa containing 4.81 per cent of ferric hydroxide, the molds produced were of extraordinary strength and toughness."

Hanley and Simonds[7] express their belief that the majority of the well bonded molding sands of this country owe their bonding qualities to the presence of colloidal hydrated ferric oxide as follows:

"In the study of many sands surprising results are obtained in connection with the effect of iron oxide on the bonding property. . . . Just what composes 'clay substance' (bond) in molding sand is not generally understood, and the following

analyses of the bonding material after it is separated from the sand may serve to clear up this point.

	New Jersey Sand	Ohio Sand	New York Sand
Silica	41.70	33.65	38.88
Iron Oxide	14.27	28.88	24.67
Alumina	25.40	18.15	22.50

In another article Hanley and Simonds[12] state:

"Ferric oxide practically always is present as an impurity in natural molding sands, and its percentages as shown by chemical analyses, often give a good indication of the amount of the bond in the sand. Ordinarily common sand without bonding properties will show an iron oxide content of 5 to 6 per cent, whereas in molding sand the ferric oxide may run from 3½ to 15 per cent. The importance of the iron content of a sand is not generally recognized, but from experience with a large number of sands with varying iron content, it has been proven that a relation exists between the percentage of iron oxide and the bonding quality. The iron content alone is not sufficient in some cases, for a sand containing five or six per cent may have almost no bonding property or it may have fairly good bond."

Bean[13] considers iron oxide detrimental in molding sand when present in small amounts. His views are criticized by Shaw.[14]

Moldenke[10] considers iron oxide bad, but admits to a limited degree its beneficial action on bond as follows:

"A further noticeable point in a number of so-called 'red' sands is a very high percentage of iron oxide, this rising to 7.5 per cent in some English sands. In one case near Vienna a sand is used with over 11 per cent iron oxide, and again another sand with nearly 12 per cent of lime. Both of these ingredients are bad, as they are fluxing, but it is interesting to note that a moderate percentage of iron oxide, if distributed over the surfaces of the quartz crystals as a stain and encrustation is not objectionable to a serious extent, as it serves as a base to hold the clay

[12] Hanley and Simonds, Foundry, 48; 743 (1920).
[13] Bean, Trans. Am. Foundrymen's Assoc., 26; 419 (1917).
[14] Shaw, Trans. Am. Foundrymen's Association, Vol. 26, 1927.

more firmly to the otherwise smooth surfaces of the grains, particularly if they are well rounded."

Boswell[15] notes that molding sands fall into two classes, naturally bonded sands which contain ferric hydroxide or certain silicates, and high silica sands which must be bonded artificially with such substances as sugar, dextrin, molasses, oil, or sulphite lees. He[16] states that the ferruginous bond improves the life of the sand and assists in the production of a smooth sound surface to the casting, particularly in the case of steel. It should be noted that this view is practically the opposite of that held by Moldenke and Bean.

Kennedy[17] calls attention to the fact that all attempts to produce artificial molding sands with the same bond as natural sand have been unsuccessful because of improper distribution of clay around the grains, giving a sand lacking in durability. He suggests that these failures are due to a lack of knowledge of the properties of iron oxide as a binder, and of ability to coat sand grains with colloidal hydrated iron oxide. Although it has been recognized for some time that colloidal ferric oxide films might have an important influence on the bond strength of sands, no quantitative data have been presented to show the effect of such films, or to account for the bond in molding sand in terms of such films.

Scope of Paper

This paper, which the authors are presenting, reports quantitative data showing the relation of colloidal ferric oxide absorbed on the sand grains and on the clay bonding material to the strength of bond in the molding sand, and the successful preparation of synthetic molding sand obtained in the course of work done on Michigan sands for the Michigan Geological Survey. The effect of colloidal iron oxide on the bond of molding sands has been determined by analytical methods on natural sands, and by synthetic methods successfully reproducing the bond of natural molding sand by the proper combination of clean unbonded sand or silica, kaolin, and ferric hydrosol.

[15] Boswell, Foundry, 47; 148-150 (1919).
[16] Boswell, Jour. Inst. Metals, 22; 292 (1919).
[17] Kennedy, *A Summary of the Literature on Molding Sand*, a mimeographed report to the A. F. A. Committee on Molding Sand Research (1921).

2. *Testing Methods*

Five four-hundred gram portions of the dried sand were weighed out and each mixed in either a tin or an aluminum dish with enough distilled water measured from a burette so that the samples would contain approximately 4, 6, 8, 10, and 12 per cent of water respectively. In some cases when only four samples were taken, the same range of percentage water content was covered at slightly different intervals. As soon as the samples were mixed they were put into clean mason jars provided with

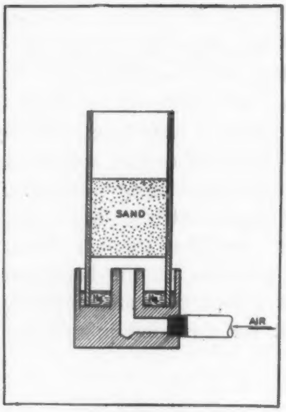

FIG. 1

rubbers and sealed. The samples were allowed to stand for at least twenty-four hours before being tested.

At the end of twenty-four hours the jars were opened and samples prepared for permeability and bond tests.

Permeability

The test used for permeability is that adopted by the American Foundrymen's Association,[18] and need not be described here. The permeability sample was rammed in a cast iron cylinder instead of the brass tube. The cylinder was then placed in the cup carrying a mercury seal (Fig. 1). This is quicker than the

[18] Transactions of the American Foundrymen's Association, vol. 31, pp. 708-721.

A. F. A. procedure and eliminates possible air leaks around the rubber stopper.

In place of the tolerance gage, used in the A. F. A. ramming apparatus, an indicator to accurately measure the length of the sand sample after ramming, consisting of a brass frame on which is pivoted a light beam carrying a knife edge contact one inch from one end, was used. A stop on the pivoted side of the beam prevents the beam from jumping out of position. A scale at the end of the indicator beam is calibrated between 1.75 and 2.25 inches by hundredths of inches by placing Johannsen gage blocks of the proper size on the pedestal underneath the rammer. The face of the rammer is caused to rest on the gage blocks, the indicator beam is swung over so that the knife edge touches the top of the steel guide rod and the point at the tip of the beam marked on the scale with a short line for each .01 inch.

The ramming operation was repeated a total of three times on each sample, after which with the weight and guide rod in position, the indicating beam was swung over until the knife edge bearing came in contact with the top of the guide rod. Thus the height of the rammed specimen was read and recorded.

In all cases the permeability was computed from the following formula:

$$\text{Permeability} = \frac{\text{cm}^3\text{. of air} \times \text{cm. height of specimen}}{\text{gms. pressure} \times \text{cm}^2\text{. of specimen} \times \text{time in minutes}}$$

Bond or Strength

The indication of the bond of molding sand has been accomplished by several methods: by the dye adsorption method and by certain physical tests such as failure of a prepared sample in transverse, tensile, compression, or shear. Because of the high precision in bond testing necessary for this work a compression test was used in which the prepared samples were crushed in the machine described in a separate paper.[19]

Rammer

The rammer used in preparing specimens for compression tests is essentially an adaptation of that described by Dietert,[20]

[19] Brown, G. G., and DeWitt, C. C., *An Automatic Precision Strength Test for Sands*, A. F. A. Preprint No. 28-15 for 1928 Philadelphia meeting.
[20] Dietert, Trans. Am. Foundrymen's Assoc., 33; 721-757 (1925).

(Fig. 3, page 242) also fully described in the previous paper.

At least three and in most cases five or more individual checks were made on each sample. The simple relation suggested by Hansen[21] that the breaking strength of a cylindrical sample of constant diameter and constant water content is inversely proportional to its height, can be applied through a narrow range in height as from 1.80 to 2.05 inches with an error of less than 2 per cent in most cases. This allowed the direct computation of the breaking strength to a height of 1.95 inches, the height at which the reported strengths are computed. The method of computation involved the multiplication of each breaking strength by the height of the sample broken, averaging the numbers so obtained and dividing their sum by 1.95. This method made it unnecessary to have all test specimens the same height.

Determination of Water Content

The water content of the sample of sand contained in each jar was determined on a whole sample of 38 to 80 grams of sand prepared in the usual manner. The sample was placed in a weighing bottle, weighed, dried for 24 hours at 105-110 degrees Cent., cooled and reweighed; the difference in weight was regarded as the water content. The water content of sand samples after testing varied slightly, not more than 0.1 per cent, from the moisture content of samples taken from the bottle. The difference was within the experimental error, so that it really made little difference whether the sample for moisture content was taken directly from the bottle or from the fragments of a test specimen.

Water Still

At the outset it was thought desirable to have available large quantities of very pure water to eliminate the uncertainty in colloidal systems for using impure water. A continuous column still of relatively high capacity was designed and built to supply this need. This equipment comprised two still bodies with steam coils, two columns interconnected and two condensers, one at the top of each column, as shown in Fig. 2.

[21] Hansen, Trans. Am. Foundrymen's Assoc., 32; 57-97 (1924).

The water is vaporized in the first still body. The vapor travels upward through the packing of the first tower, a portion of it is refluxed down the tower and is discarded through a trap at the bottom thus effecting a separation of the less volatile impurities. The remainder of the vapor travels across to the second tower where it is condensed, flows down through tower packing, meeting as it comes down an upward current of steam generated from pure distilled water in the second still body, part of which escapes through an orifice in the top of the second tower. At the base of the second tower some of the water is tapped off through a trap, the balance going into the still body to be revaporized to furnish the steam for scrubbing the water coming down the column

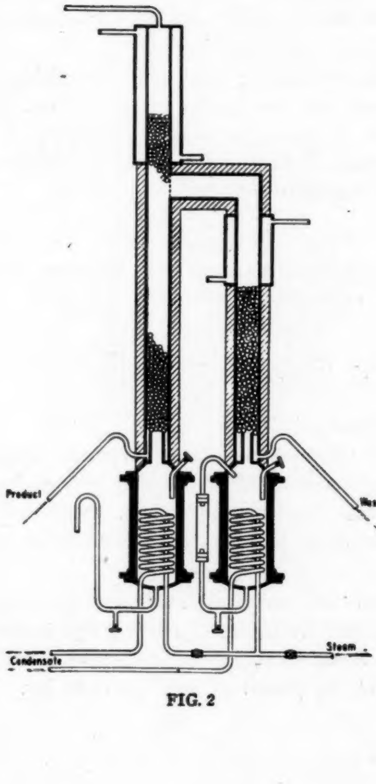

FIG. 2

free of more volatile impurities and gases.

All parts of the still coming in contact with the water or water vapor are made of block tin. The packing in the columns is made of 1/40 inch sheet block tin cut and formed into Raschig rings 3/4 inch diameter by 3/4 inch thick.

3. *Analysis of Natural Molding Sand*

For the purpose of investigating the cause of bond in natural molding sand a sample of fresh Albany molding sand was adopted for testing and analysis.

Natural Molding Sand

The natural Albany molding sand was carefully dried in air, and at 105-110 degrees Cent. thoroughly mixed, one sample of 2,000 grams obtained by quartering was taken and preserved in a glass jar.

This sand was tested for bond and permeability by the methods described and with the results given in Table 2. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3 and the permeability plotted as a function of moisture content in Fig. 4.

Table 2

PROPERTIES OF THE NATURAL MOLDING SAND

Percentage	Breaking Strength in Compression		
H_2O	lbs./sq. in.	gms./sq. cm.	Permeability
3.3	1.760	122.9	29.2
5.2	1.906	137.6	30.1
7.14	2.064	144.15	31.8
9.82	2.137	148.2	29.9
11.83	2.098	146.4	27.0

Natural Base-Material

The natural base-material was prepared from the natural molding sand by removing all of the clay silt, or loam surrounding the individual sand grains, which could be removed by siphoning, or washing with water, according to the following method.

The so-called "clay substance" was removed from the natural Albany molding sand by repeated washing and shaking with tepid distilled water. Some 40 pounds of sand were distributed in clean quart mason jars, ½ pound of sand to each jar. Twenty jars

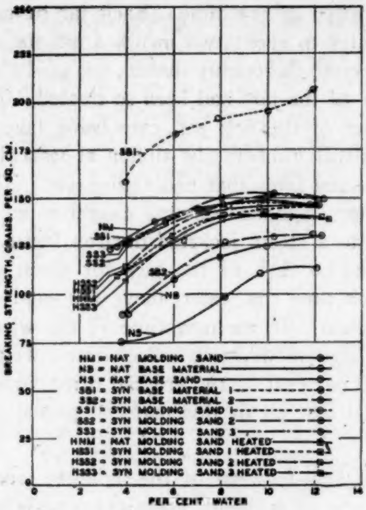
BREAKING STRENGTH, GRAMS PER SQ. CM.
PER CENT WATER
NM = NAT MOLDING SAND
NB = NAT BASE MATERIAL
NS = NAT BASE SAND
SB1 = SYN BASE MATERIAL 1
SB2 = SYN BASE MATERIAL 2
SS1 = SYN MOLDING SAND 1
SS2 = SYN MOLDING SAND 2
SS3 = SYN MOLDING SAND 3
HNM = NAT MOLDING SAND HEATED
HSS1 = SYN MOLDING SAND 1 HEATED
HSS2 = SYN MOLDING SAND 2 HEATED
HSS3 = SYN MOLDING SAND 3 HEATED

FIG. 3

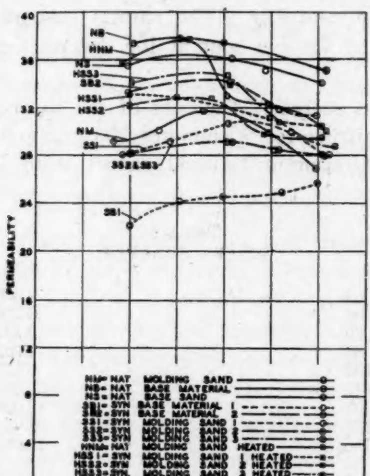
PERMEABILITY
PER CENT WATER
NM = NAT MOLDING SAND
NB = NAT BASE MATERIAL
NS = NAT BASE SAND
SB1 = SYN BASE MATERIAL 1
SB2 = SYN BASE MATERIAL 2
SS1 = SYN MOLDING SAND 1
SS2 = SYN MOLDING SAND 2
SS3 = SYN MOLDING SAND 3
HNM = NAT MOLDING SAND HEATED
HSS1 = SYN MOLDING SAND 1 HEATED
HSS2 = SYN MOLDING SAND 2 HEATED
HSS3 = SYN. MOLDING SAND 3 HEATED

FIG. 4

of sand were treated at one time. Each jar of sand was filled with distilled water to about two inches from the top. The jar was tightly stoppered, thoroughly shaken, the sand allowed to settle until the last one of the jars had been so treated. The water was then siphoned out of the first jar, care being taken to have the end of the 3/16 inch rubber tube siphon at least 3/4 inch above the level of the sand layer that had settled out. The water suspension of silt, etc., siphoned off was caught in an enameled pan and transferred to a steam jacketed duriron kettle. This operation was repeated on each of the jars for about two weeks, at the end of which time the water above the sand could be seen to be perfectly clear. In the meantime all the washings and silt had been evaporated to dryness, collected and weighed. It constituted about 13 per cent of the original dried sample. A screen analysis indicated that all of this material passed through a 270 mesh sieve.

The natural *base-material* of the molding sand was washed out of the jars into an enameled container, excess water decanted through a filter paper on a buchner funnel, the sand so caught returned to the container. The natural base-material was air dried, then dried for one hour at 105 degrees Cent. and mixed for testing.

The screen analysis (Table 3) of the natural base-material was made by sifting for 30 minutes 100 grams of the material obtained by quartering in the usual manner, using U. S. S. screens and a rotap machine.

Table 3
SCREEN ANALYSIS

Mesh	*% on*
50	0.028
60	0.268
70	0.422
80	0.235
100	0.622
140	20,082
200	40.600
270	25.950
Pan	11.990
	100.197

The base material was tested for bond and permeability by the methods described and with the results given in Table 4. The

compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3 and the permeability in Fig. 4.

Table 4

PROPERTIES OF THE NATURAL BASE-MATERIAL

Percentage H_2O	—Breaking Strength in Compression— lbs./sq. in.	gms./sq. cm.	Permeability
4.11	1.274	88.9	37.3
6.03	1.538	107.5	37.7
7.97	1.704	119.0	37.5
9.97	1.782	124.5	36.4
12.28	1.865	130.25	35.2

The Natural Base-Sand

The natural base-sand was prepared by removing the adsorbed material from the natural base-material. A large portion of the natural base-material was treated with 1 per cent caustic soda solution and shaken, then washed with water, and digested with hot 1-1 HCl to dissolve any film of hydrated oxides. The sand was washed repeatedly by decantation alternately at first with hot dilute acid and hot distilled water, finally with hot distilled water until the washings were free from acid. The sand after this treatment is hereafter referred to as the natural base-sand. This material was kept under distilled water which was changed frequently until no more acid, as determined by the colorimetric hydrogen ion method diffused into the water. The base-sand was then collected and dried at 110 degrees Cent. Its general appearance had changed from dull greenish brown to a light gray shot with sparkling bits of mica.

The iron oxide removed from the base material by hot 1-1 HCl was determined and found to be 2.6 per cent of the base material. The total weight of ignited oxides removed by hot 1-1 HCl was 0.0272 grams per gram of sample or 2.72 per cent. This analysis indicated that practically all of the material removed by the HCl was iron of one form or another.

The natural base sand was tested for bond and permeability by the methods described with the results given in Table 5. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3 and the permeability in Fig. 4.

Table 5

THE PROPERTIES OF THE NATURAL BASE-SAND

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.85	1.081	75.5	35.6
8.25	1.402	97.9	36.2
9.70	1.581	110.5	35.2
12.09	1.617	113.0	34.2

4. *Synthesis of Molding Sand*

In order to duplicate the properties of the natural base-material from the base-sand it is necessary to restore in all essentials the original surface conditions to the base sand. This was accomplished by adding to the base sand a synthetic iron hydrosol in place of the natural colloid removed, thereby forming a synthetic base-material.

For the duplication of the properties of the natural molding sand from the natural or synthetic base-material it is necessary to restore the bond material in all essentials. This was accomplished by adding to the natural base-material and to the synthetic base-material, synthetic bond materials. In preparing the synthetic base-material and the synthetic molding sand, silica, kaolin and an iron hydrosol were used.

Preparation of Silica

Two hundred pounds of pure fused silica ground to pass 100 mesh was procured from the Thermal Syndicate Ltd. of Brooklyn, N. Y. The principal impurity of this material was finely divided particles of iron, just enough so that when the silica was treated with dilute acid, a trace of iron was found by the sulphocyanate test.

A slightly alkalinity was also noted in the first portions of wash water from the silica.

About 100 pounds of silica was washed by decantation with water from the still, until the washings showed no trace of their original alkalinity. Incidentally this treatment removed most of the finely divided iron and some dust. The silica was thrown onto a large buchner funnel, where a large portion of the water was removed by suction. It was placed on a large block tin tray, air dried, then dried at 110 degrees Cent.

After drying the silica was thoroughly mixed and three samples of 2,000 grams each sealed in glass jars. The remainder of the silica was kept in a clean paper lined burlap sack from which it was drawn as needed. A portion of this sand was sifted through a 270 mesh sieve to provide fused silica for the synthetic "bond-material" No. 1.

Preparation of Kaolin

A quantity of Merck's kaolin and also ten pounds of a non-plastic kaolin furnished by the research laboratory of the Norton Company through the courtesy of Messrs. Kilpatrick and Beecher of that organization were washed by decantation with pure distilled water, dried at 105-110 degrees Cent. and pulverized to pass 270 mesh.

Preparation of Iron Hydrosol

The iron hydrosol or suspension of hydrated iron oxide was prepared by a method similar to that of Neidle and Barab.[22]

Ninety grams of c.p. $FeCl_3.6H_2O$ was dissolved in 400 cubic centimeters H_2O. To this was added dropwise with constant stirring 150 cubic centimeters of ammonium hydroxide solution made by diluting 35 cubic centimeters 0.9 specific gravity NH_4OH to 150 cubic centimeters. The solution was allowed to stand for twenty-four hours, filtered through paper on a buchner funnel, diluted to two liters, and dialyzed cold by a collodion bag for twenty-four hours. The dialysis was continued at 70 to 90 degrees Cent. The collodion bags were changed each day for the first week and every other day thereafter until the dialysis was completed. This point was considered to be reached when 500 cubic centimeters of the solution from the interior of the collodion bags evaporated to 50 cubic centimeters showed no test for iron by the sulphocyanate method or chlorine by the usual procedure with silver nitrate. The analysis of the hydrosol, using the method

[22] Neidle and Barab, Jour. Am. Chem. Soc., 39; 79.

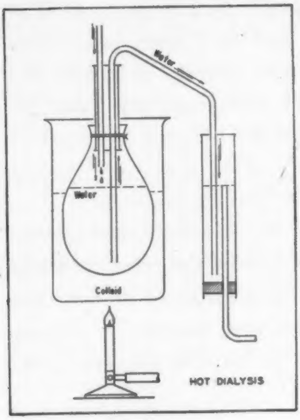

FIG. 5

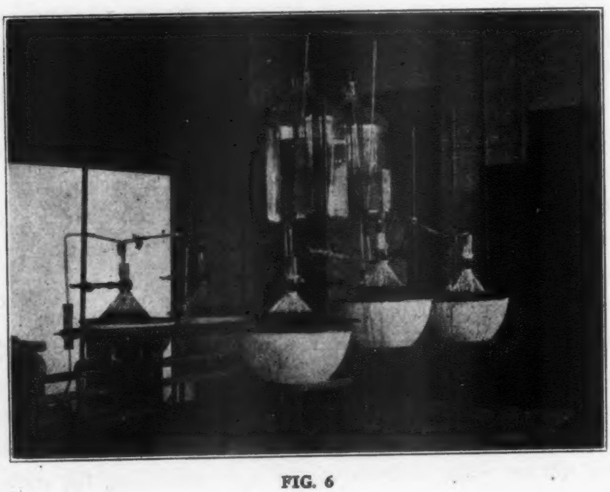

FIG. 6

of Thomas[23] for chlorine and a gravimetric method for iron as iron oxide, gave the following result: $Fe_2O_3 : FeCl_3 = 15.0 : 1$.

The general scheme of the dialyzing operation is shown in Fig. 5. Two batteries of three dialyzing units in parallel, Fig. 6, were each fed from a five gallon water bottle. The rate of feed during sixteen hours a day was about 1½ to 2 liters per hour, for the remaining eight hours approximately half of that rate. The outer containers were Vollrath enameled steel pans holding about six liters. Other than a slight stain on the enamel these pans showed no marked deterioration after one month's continuous use for this purpose. At the beginning of the operation ordinary distilled water was used. The dialysis was completed with pure water from the continuous still described above. The dialyzed iron hydrosol was stored in glass bottles kept in a cupboard away from light.

Adsorption of the Iron Hydrosol

In preparing the synthetic bonds and sands the kaolin and sand, prepared separately as first described, were weighed out with an excess of water, then mixed thoroughly with the proper quantity of the iron hydrosol. For the sand sufficient hydrosol was used to give an Fe_2O_3 content of 1 per cent; for the clay the Fe_2O_3 was 0.44 per cent. The mixture of sand and hydrosol, or clay and hydrosol, was evaporated to dryness at or about 100 degrees Cent. in a water bath, then dried at 105 degrees Cent. for one hour, and in the case of the clay broken up so as to go through a 270 mesh sieve. This dry synthetic mixture was put through a sieve, one size larger than the largest grain of sand in the mixture, four times. The dry material was further mixed by spreading on a block tin platter and stirring systematically with a tin spoon, after which the synthetic material was used directly in making up sand samples for testing.

Synthetic Bond Materials No. 1 and No. 2

A chemical analysis (Table 6) of the clay-like bond material washed out of the molding sand was made. It will be noted that

[23] Thomas, Jour. Am. Chem. Soc., 39; 79.
[24] Mellor, Trans. Eng. Ceram. Soc., 13 (1913-14).
[25] Samoylov, Bulletin de l'Academie Imperial des Sciences de St. Petersburg VI Ser. 31 (1909).

the water of composition of the kaolin is deducted from the total loss on ignition in the rationalized analysis[24],[25].

Table 6
ANALYSIS OF NATURAL BOND MATERIAL

Chemical Analysis		Rationalized Analysis	
Alumina (Al_2O_3)	6.20%	15.4 %	Kaolin
Iron Oxide (Fe_2O_3)	2.60%	2.6 %	Fe_2O_3
Silica (SiO_2)	86.10%	78.86%	SiO_2
Loss on Ignition	3.6 %	1.6 %	Loss on Ignition
Lime (CaO)	0.11%	0.11%	

From this analysis, assuming that all the alumina was in the form of kaolin and that both kaolin and silica grains were coated with hydrated iron oxide, a similar synthetic bonding material was made up of the proper amounts of fused silica and kaolin ground to pass 270 mesh and carrying adsorbed ferric hydrate. This material, referred to hereafter as synthetic bond No. 1, was air dried, then dried at 105 degrees for one hour and preserved in stoppered bottles until used.

Another bond material in which the fused silica passing 270 mesh was replaced by natural base-sand of the same size obtained from the original Albany molding sand was prepared. These grains were also coated with a film of hydrated iron oxide. The synthetic bond material so obtained will be referred to hereafter as synthetic bond No. 2. It was air dried, then dried at 105 degrees for one hour, and preserved in stoppered bottles until used.

Base-Material No. 1

The synthetic base-material No. 1 was made by adding to ground, fused silica of approximately the same screen analysis as the natural base material, in the manner described 1 per cent of hydrated iron oxide.

The synthetic base-material No. 1 was tested for bond and permeability by the methods described with the results given in Table 7. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3, and the permeability in Fig. 4.

Table 7
PROPERTIES OF SYNTHETIC BASE MATERIAL NO. 1

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.97	2.16	158.0	22.2
6.09	2.60	183.5	24.2
7.93	2.72	191.5	24.6
10.04	2.77	195.0	25.0
11.93	2.92	206.0	25.7

Synthetic Base-Material No. 2

The synthetic base-material No. 2 was made by adding to the natural base-sand in the manner described 1 per cent of hydrated iron oxide.

The synthetic base-material No. 2 was tested for bond and permeability by the methods described and with the results given in Table 8. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3, and the permeability in Fig. 4.

Table 8

PROPERTIES OF NATURAL BASE SAND PLUS 1 PER CENT HYDRATED IRON OXIDE, SYNTHETIC BASE MATERIAL NO. 2

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.85	1.274	88.9	33.4
8.2	1.786	125.6	34.2
10.31	1.852	129.4	32.0
11.93	1.885	131.7	31.5

Synthetic Molding Sands Nos. 1, 2, and 3

The synthesis of a molding sand having properties similar to those of the natural sand was attempted in three independent ways. To natural base-material thirteen per cent of synthetic bond No. 1 was added. To the synthetic base material No. 2 thirteen per cent of synthetic bond material No. 1 was added. To the synthetic base material No. 2 thirteen per cent of synthetic bond No. 2 was added.

The first, synthetic molding sand No. 1, was tested for bond and permeability by the methods described and with the results given in Table 9. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3, and the permeability in Fig. 4.

The second, synthetic molding sand No. 2, was tested for bond and permeability by the methods described and with the results given in Table 10. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3, and the permeability in Fig. 4.

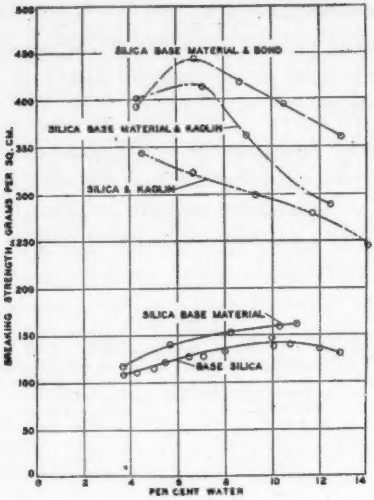
SILICA BASE MATERIAL & BOND
SILICA BASE MATERIAL & KAOLIN
SILICA & KAOLIN
SILICA BASE MATERIAL
BASE SILICA
BREAKING STRENGTH, GRAMS PER SQ. CM.
PER CENT WATER

FIG. 7

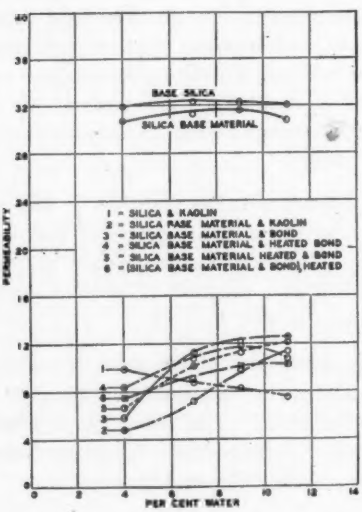
BASE SILICA
SILICA BASE MATERIAL
1 = SILICA & KAOLIN
2 = SILICA BASE MATERIAL & KAOLIN
3 = SILICA BASE MATERIAL & BOND
4 = SILICA BASE MATERIAL & HEATED BOND
5 = SILICA BASE MATERIAL HEATED & BOND
6 = (SILICA BASE MATERIAL & BOND) HEATED
PERMEABILITY
PER CENT WATER

FIG. 8

The third, synthetic molding sand No. 3, was tested for bond and permeability by the methods described and with the results given in Table 11. The compressive strength in grams per square centimeter is plotted as a function of moisture content in Fig. 3, and the permeability in Fig. 4.

Table 9

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 1

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.65	1.786	124.7	28.1
5.67	1.965	137.2	29.2
8.15	2.095	146.2	30.8
10.8	2.097	146.4	30.0
12.2	2.095	146.2	28.0

Table 10

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 2

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
4.06	1.912	126.1	28.2
8.11	2.138	150.0	29.2
10.33	2.190	152.5	28.6
12.17	2.123	149.0	28.2

Table 11

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 3

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.98	1.806	126.1	28.2
8.37	2.077	146.7	29.2
10.08	2.17	151.8	28.6
12.4	2.12	149.1	28.2

Discussion

The graphs in Fig. 3 show that the presence of the natural film of adsorbed material has a measurable effect on the strength of the base sand. The absence of the bond material or "clay substance" causes a marked decrease in the strength of the natural molding sand. The graphs also indicate that the synthetic base-material No. 2 made from the natural base-sand and iron hydrosol is slightly stronger than the natural base-material; however, the agreement is good.

The general concurrence of the data on the strength of the synthetic molding sands as compared with that of the natural molding sands is good, and indicates that the physical strength of the natural molding sand has been substantially duplicated by that of the synthetic molding sands.

The graphs in Fig. 4 show that the presence of the adsorbed film on the sand grains gives a slightly higher permeability than

the sand alone. This fact and that the permeability of the natural molding sand rises to a maximum with increasing water content can be explained as due to swelling of colloidal particles and to the agglomeration of the sand grains with the bond material, thus causing larger envelopes of grain particles, with consequent lowering of resistance to air flow. When the pore space actually begins to decrease, due to the filling up of the pore spaces with water, the permeability to gases decreases.

The agreement of the values of permeability of the different synthetic sands is satisfactory. The permeability of the synthetic sands is more nearly constant with varying water content, which in foundry work is to be desired.

An interesting sidelight is had on the influence of grain shape by observing the behavior of base material No. 1 made up of ground fused silica of the same screen analysis as the natural base material. In this instance the only variable is the shape of the grain. The angular grains of the crushed silica have a higher strength and lower permeability than the more rounded grains of the natural base-sand which has a lower strength and higher permeability. This function of grain shape and permeability was first recognized and accounted for by King and Schlichter.[3] Angular grains when packed together have, in general, more pore space and are less permeable.

5. *The Effect of Heat on Natural and Synthetic Molding Sands*

The behavior of molding sands when heated has been studied by a number of investigators. The experience of Dietert[26] and Littlefield[2] indicates that the loss of bond observed on heating a natural molding sand to 600 degrees Fahr. for two hours gives a good indication of its utility as a molding sand. It is interesting to note in this connection that Von Weiman and Hgiward[27] have shown that Goethite natural crystalline ferric hydrate ($Fe_2O_3H_2O$) loses most of its water when heated at 608 degrees Fahr. (320 degrees Cent.). However, hydrated iron oxide[28,29]

[26] Dietert, Trans. Am. Foundrymen's Assoc., 32; 24-52 (1924).

[27] *Colloid Chemistry*, Jerome Alexander, vol. 1, p. 653. Chem. Cat. Co., New York, 1926.

[28] Paneth and Vorwerk, Zeit. phys. chem., 101; p. 445 (1922).

[29] Hahn and Muller, Zeit. f. Electrochem., 29; p. 189 (1923). Hahn, Naturwissenschaften, 12; p. 1140 (1924). Hahn, Liebig. Annalen, 440; p. 121 (1924).

appears to be the only metallic hydroxide that will adsorb water and regain its initial surface condition after being dried or heated to this temperature.

For the purpose of indicating the relative durability of the synthetic and natural molding sands, the samples were heated at 600 degrees Fahr. for three hours, then moistened and tested in the manner described. This treatment is more severe than that recommended by Dietert[27] and Littlefield[2] in that heating was continued for three hours instead of two.

The heating of the sand was done in an ordinary Fries thermostatic oven provided with a large capacity heating coil and a heavy-duty thermo-regulator. The temperature was recorded on a calibrated Tycos nitrogen filled mercury thermometer, the bulb of which was thrust into the sand being heated, care being taken that the thermometer bulb did not touch the metal pan. As the thickness of the sand layer in the pan did not exceed ½ inch a small part of the thermometer bulb was exposed to the heated air of the thermostat. The temperature of the thermostat was held constant to ± 2 degrees Fahr.

The dry samples of sand were spread in layers ½ inch thick in a black iron baking pan, placed in the oven, and allowed to come to a temperature of 600 degrees Fahr. at which temperature the material was held for three hours.

Properties of Natural Molding Sand, Heated

The natural Albany molding sand heated at 600 degrees Fahr. for three hours was tested for bond and permeability by the methods described with the results given in Table 12. The compressive strength plotted as a function of the moisture content is shown in Fig. 3 with that of the unheated sand for comparison. The permeability plotted as a function of moisture content is shown in Fig. 4.

Table 12

PROPERTIES OF NATURAL ALBANY MOLDING SAND HEATED TO 600 DEGREES FAHR. FOR THREE HOURS

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.6	1.545	108.6	35.9
6.46	1.760	127.2	37.8
8.11	1.975	138.8	33.1
9.82	2.013	141.6	32.4
12.32	1.99	140.0	30.1

Properties of Synthetic Molding Sands No. 1, No. 2, No. 3

Synthetic molding sands Nos. 1, 2 and 3 heated to 600 degrees Fahr. for three hours were tested for bond and permeability by the methods described with the results given in Tables 13, 14 and 15. The compressive strengths are plotted as a function of the moisture content in Fig. 3 and the permeabilities in Fig. 4.

Table 13

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 1 (NATURAL BASE MATERIAL PLUS SYNTHETIC BOND NO. 1, HEATED)

Percentage	Breaking Strength in Compression		
H_2O	lbs./sq. in.	gms./sq. cm.	Permeability
3.92	1.57	110.8	33.2
5.95	1.84	129.8	33.0
8.2	2.01	141.9	34.1
9.9	2.02	142.6	31.3
12.1	2.08	146.5	30.6

Table 14

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 2 (SYNTHETIC BASE MATERIAL NO. 2 PLUS SYNTHETIC BOND MATERIAL NO. 1), HEATED

Percentage	Breaking Strength in Compression		
H_2O	lbs./sq. in.	gms./sq. cm.	Permeability
3.95	1.62	114.2	32.4
7.40	2.03	142.8	32.9
9.65	2.068	144.3	29.8
12.16	2.08	146.3	29.6

Table 15

PROPERTIES OF SYNTHETIC MOLDING SAND NO. 3 (SYNTHETIC BASE MATERIAL NO. 2 PLUS SYNTHETIC BOND MATERIAL NO. 2), HEATED

Percentage	Breaking Strength in Compression		
H_2O	lbs./sq. in.	gms./sq. cm.	Permeability
4.02	1.51	106.4	34.2
8.16	2.01	141.4	34.8
10.31	1.99	140.0	30.9
12.63	1.97	139.0	28.9

Discussion

The strength of the natural and synthetic molding sands are decreased to almost the same degree by heating to 600 degrees Fahr. for three hours. This affords further evidence that the natural molding sand has been substantially duplicated by synthetic means.

The permeabilities of the natural and synthetic sands are increased to about the same degree by the heat treatment.

The data presented indicate that the bond, permeability, and durability of high grade natural molding sand such as is known to the trade as "Albany Sand" can be substantially duplicated and restored by synthetic means using adsorbed ferric hydrogel as an agent to prepare the surfaces of the sand and clay, and that ferric

hydrogel is an important factor in the bond of high grade natural bonded molding sands.

6. *Bonded Systems from Pure Ingredients*

The numerous constituents of natural molding sand identified by Condit[8] are not essential to the properties of molding sand. It has just been shown that the properties of a high grade molding sand may be duplicated by the use of only three materials, sand, kaolin and ferric hydrosol. For scientific reasons, at least, it is desirable that bonded systems of pure silica, kaolin and ferric hydrosol be investigated as well as the ordinary molding sand. The materials used for this purpose were the ground fused silica, the kaolin and the ferric hydrosol already described.

The Bond Material

The bond material used in the case of the pure materials was kaolin and kaolin treated with 0.44 per cent iron oxide as hydrated iron oxide. The kaolin untreated with the hydrosol was used to determine the effect of the absence of hydrated iron oxide. Fifteen per cent by weight of kaolin or kaolin plus 0.44 per cent iron oxide was used as the bond material in this work with pure materials.

Base Silica

In the synthesis of the molding sand previously described the base sand furnished the starting point. In this case, the ground fused silica was used.

The base silica was tested for bond and permeability by the methods described and with the results given in Table 16. The compressive strength as a function of moisture content for the three samples is plotted in Fig. 7 and the permeability in Fig. 8.

Table 16

Percentage H_2O	—Breaking Strength in Compression— lbs./sq. in.	gms./sq. cm.	Permeability
3.69	1.541	108.6	...
4.00	....	....	32.0
4.32	1.587	110.9	...
5.01	1.644	115.6	...
5.5	1.733	121.1	...
6.48	1.806	126.2	...
7.00	....	....	32.4
7.17	1.81	127.2	...
8.0	1.902	132.9	...
9.0	....	....	32.4
10.06	2.098	146.5	...
10.1	1.975	138.0	...
10.82	1.991	140.0	...
11.0	....	....	32.1
12.0	1.965	135.9	...
12.9	1.885	131.7	...

Silica Base Material

The synthesis of the silica base material was accomplished by the same method used in the preparation of the base material of the synthetic molding sand, using the base silica and ferric hydrosol. One per cent of ferric oxide as hydrosol was added to the silica.

The silica base-material was tested for bond and permeability by the methods described. The results are plotted in Figs. 7 and 8 and tabulated in Table 17.

Table 17

PROPERTIES OF SILICA BASE MATERIAL (BASE SILICA PLUS 1 PER CENT HYDRATED IRON OXIDE)

Percentage H_2O	—Breaking Strength in Compression— lbs./sq. in.	gms./sq. cm.	Permeability
3.66	1.647	115.7	...
4.00	...	....	30.8
5.74	1.99	140.0	...
7.00	...	....	31.4
8.32	2.17	152.5	...
9.00	...	....	31.7
10.35	2.27	159.5	...
11.00	...	....	30.8
11.05	2.28	161.0	...

Mixture of Silica and Kaolin

A mixture of 85 per cent ground fused silica and 15 per cent kaolin was prepared in the manner described.

The mixture of silica and kaolin was tested for bond and permeability by the methods described with the results given in Table 18 and plotted in Figs. 7 and 8.

Table 18

PROPERTIES OF SILICA—KAOLIN MIXTURE

Percentage H_2O	—Breaking Strength in Compression— lbs./sq. in.	gms./sq. cm.	Permeability
4.00	...	....	9.9
4.53	4.90	344.3	..
6.66	4.42	322.0	..
7.00	...	....	8.8
9.00	...	....	8.4
9.33	4.26	299.3	..
11.00	...	....	7.6
11.76	3.99	280.8	..
14.14	3.518	245.0	..

Silica Base Material Plus 15 Per Cent Kaolin

The combination of the silica base-material and 15 per cent kaolin was brought about in the same manner and tested with the results given in Table 19 and plotted in Figs. 7 and 8.

Table 19

PROPERTIES OF SILICA BASE MATERIAL PLUS 15 PER CENT KAOLIN

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
4.00	...	....	4.8
4.28	5.71	401.5	..
7.00	...	....	7.2
7.05	5.895	414.5	..
8.96	5.14	361.5	..
9.00	...	....	9.9
11.00	...	....	11.4
12.46	4.11	289.0	..

Silica Base Material Plus 15 Per cent "Bond Material" (Kaolin with 0.44 Per Cent Iron Oxide as Hydrated Iron Oxide)

To the silica base-material 15 per cent of kaolin containing 0.44 per cent of iron oxide was added in the manner described.

The combination of silica base-material with kaolin carrying 0.44 per cent iron oxide as hydrated iron oxide was tested for bond and permeability by the methods described and with the results given in Table 20 and plotted in Figs. 7 and 8.

Table 20

PROPERTIES OF SILICA BASE MATERIAL PLUS 15 PER CENT KAOLIN CONTAINING 0.44 PER CENT IRON OXIDE AS HYDRATED IRON OXIDE

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
4.00	....	....	5.8
4.23	5.58	392.2	...
6.72	6.32	444.0	...
7.00	...	....	11.3
8.65	5.96	418.2	...
9.00	...	....	12.3
10.50	5.62	395.0	...
11.00	...	....	12.6
12.93	5.115	360.0	...

High Grade Molding Sand from Unbonded Beach Sand

The results of this work clearly indicate the possibility of preparing high grade synthetic bonded molding sands to meet specifications for certain uses. As a demonstration a clean beach sand from the Michigan City district was mixed; treated with iron hydrosol and mixed with 15 per cent kaolin containing 0.44 per cent hydrated iron oxide as described. This synthetic material was tested for bond and permeability by the methods described with the results given in Table 21 and plotted in Fig. 9.

Table 21

PROPERTIES OF MICHIGAN CITY SAND BASE MATERIAL PLUS 15 PER CENT KAOLIN CONTAINING 0.44 PER CENT HYDRATED IRON OXIDE

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.41	8.44	592	..
5.90	8.6	604	45
8.32	9.63	676	45
9.89	2.69	189	..
11.44	2.12	149	..

The same sample was then dried and heated at 600 degrees Fahr. for three hours, then tested for bond and permeability with the results given in Table 22 and plotted in Fig. 9.

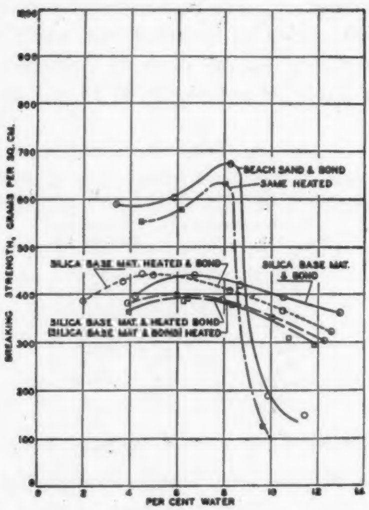

FIG. 9

Discussion

The presence of the surface film of hydrated iron oxide on the fused silica base causes an increase in the strength of the material similar in character to that observed when the natural base-sand was treated with the iron hydrosol.

The presence of the hydrated iron oxide film on the silica is shown to exert a marked influence on the strength of silica-kaolin mixtures. Hydrated iron oxide films on both silica and kaolin give a further increase in strength especially at the higher water contents.

Table 22

PROPERTIES OF MICHIGAN CITY BASE MATERIAL PLUS 15 PER CENT KAOLIN CONTAINING 0.44 PER CENT HYDRATED IRON OXIDE HEATED TO 600 DEGREES FAHR. FOR THREE HOURS

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
4.5	7.92	556	..
6.2	8.38	581	..
8.1	9.02	633	55
9.7	1.79	125.5	..
12.0	...	...	..

The permeability of the silica-kaolin mixtures decreases with successive additions of water while the permeability of the silica-kaolin-iron oxide combinations shows an increase with water content. This may be taken as an indication that adsorbed hydrated iron oxide in the particles of silica is present as a gel which takes up water and swells, thereby forming larger particles tending to become spherical or causing the separate grains to agglomerate, in either case increasing the permeability of the mass.

Simple mixtures of clay and sand are not satisfactory for molding sands unless the clay is so distributed over the sand grains as to exert a cementing or bonding action between the sand grains. The addition of clay to sand or silica increases the bond as indicated in Fig. 7, but the full bonding power of sand is not developed unless there be some adsorbed colloidal gel to aid in bonding the sand and clay.

The results so far obtained in this purely laboratory investigation clearly indicate the importance of colloidal matter in molding sand and show how the properties of a high grade molding sand may be reproduced synthetically if this colloid matter or adsorbed ferric hydrosol be properly applied to the sand and bond.

The Cause of the Decrease in Bond Strength on Heating Molding Sands to 600 Degrees Fahr.

By C. C. DeWitt,* Houghton, Mich., and G. G. Brown,† Ann Arbor, Mich.

The importance of the durability test in evaluating molding sands is now generally recognized. But no data are available as to what part of the sand or bond is most affected by this treatment.

Having shown the importance of adsorbed colloidal ferric hydroxide in the bond structure of high grade molding sands in the previous paper,[1] it seemed that valuable information might be obtained if tests were conducted to show what effect heating to 600 degrees Fahr. had upon the clay bond and the ferric hydrogel bond constituents. For this purpose the synthetic bonded material made from pure silica, kaolin, and ferric hydrogel was used. The choice of pure materials was made to eliminate so far as possible the confusing influence of unknown impurities. In these tests the silica base material and the bond material[1] were heated separately, then mixed with unheated bond and base material respectively. These mixtures were then compared with the unheated bonded system, prepared by mixing unheated base mate-

*Professor of Chemistry, Michigan College of Mining and Technology.
†Professor of Chemical Engineering, University of Michigan.
[1] DeWitt, C. C., and Brown, G. G., *The Influence of Ferric Hydrogel in the Bonding of Natural Molding Sands,* A. F. A. Preprint No. —, to be presented at 1928 Philadelphia meeting.

rial and bond material, and with the bonded system mixed before heating.

The kaolin bond material containing the adsorbed hydrated iron oxide was heated at 600 degrees Fahr. for three hours, cooled to room temperature, and mixed with the silica base material in the manner previously described. This mixture was tested for bond and permeability with the results given in Table 1 and plotted in Fig. 8, page 264, and Fig. 9, page 272.

Table 1

PROPERTIES OF THE SILICA BASE MATERIAL PLUS (KAOLIN CONTAINING 0.44 PER CENT IRON OXIDE AS HYDRATED IRON OXIDE, HEATED TO 600 DEGREES FAHR. FOR THREE HOURS)

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.9	5.455	383.5	...
4.0	....	....	8.4
6.0	5.685	400.0	...
7.0	....	....	10.8
7.95	5.528	390.5	...
9.0	....	....	11.85
10.1	5.02	352.0	...
11.0	....	....	10.8
12.3	4.32	304.0	...

The silica base material was heated at 600 degrees Fahr. for three hours, cooled to room temperature, and combined with the unheated kaolin bond material in the manner described. This mixture was tested for bond and permeability with the results given in Table 2 and plotted in Figs. 1 and 2.

Table 2

PROPERTIES OF SILICA BASE MATERIAL HEATED AT 600 DEGREES FAHR. FOR THREE HOURS PLUS 15 PER CENT KAOLIN CONTAINING 0.44 PER CENT IRON OXIDE AS HYDRATED IRON OXIDE

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
2.0	5.515	389	...
3.7	6.116	430	...
4.0	...	...	6.7
4.55	6.34	446	...
5.0	6.274	441	...
7.0	...	...	10.2
8.25	5.76	409.5	...
9.0	...	...	11.3
10.55	5.21	366.2	...
11.0	...	...	12.1
12.6	4.60	322.9	...

The silica base-material was mixed with the bond material (kaolin with 0.44 per cent iron oxide as hydrated iron oxide) and the mixture heated at 600 degrees Fahr. for three hours.

This heated mixture was tested for bond and permeability with the results given in Table 3 and plotted in Fig. 8, page 264, and

Table 3

PROPERTIES OF SILICA BASE MATERIAL PLUS 15 PER CENT KAOLIN CONTAINING 0.44 PER CENT HYDRATED IRON OXIDE, HEATED AT 600 DEGREES FAHR. FOR THREE HOURS AFTER MIXING

Percentage H_2O	Breaking Strength in Compression lbs./sq. in.	Breaking Strength in Compression gms./sq. cm.	Permeability
3.96	5.204	366	...
4.00	...	...	7.5
6.28	5.51	388	...
6.42	5.60	394	...
7.00	...	...	9.1
8.4	5.40	380	...
9.0	...	...	10.0
10.8	4.405	310	...
11.0	...	...	10.4
11.86	4.222	295	...

Discussion

Heating the silica base material before mixing it with the bond material has no noticeable effect on the maximum strength of the bonded system. This indicates that the loss in bond on heating, at least to 600 degrees Fahr. for three hours is not due to any change in the ferric hydrogel adsorbed on the silica. This fact is a further verification of that report by Hahn[2] that hydrated ferric oxide is reversibly pektized on heating. Heating the silica base does seem to shift the point of maximum strength toward drier mixtures from about 7 to 5 per cent water content. This may be due to the heated gel being more easily wetted and therefore weaker at the higher water contents.

On the other hand, heating the bond material before mixing with the silica base material causes the mixture to lose practically all of the strength lost on heating the mixture. This clearly indicates that the loss in bond on heating is due entirely to changes in the clay bond as distinct from the sand or colloidal ferric hydrogel. The mineral kaolinite ($Al_2O_3.2\ SiO_2.2\ H_2O$) has shown no evidences of decomposition at temperatures as low as 600 degrees Fahr.[3] Other hydrous aluminum silicates probably present in kaolin such as halloysite and allophane[4] show evidences of dehydration at temperatures as low as 300 degrees Fahr. (150

[2] Hahn, Zeit. f. Elecktrochemie, 29; (1923), p. 189; Naturwiss., 12; (1924), p. 1140; Liebig's Annalen, 440; (1924), p. 121.
[3] S. Satoh, J. Am. Cer. Soc., IV, p. 182 (1921).
[4] Le Chatelier, Compt. Rendu., 104; p. 1443 (1887); Ding. Polyt. J., 265; p. 94 (1887). Bigot, A., Compt. rendu., 176; p. 91 (1923).

degrees Cent). Bigot reports that clays are partially irreversibly pektized at 350 to 600 degrees Cent.

With these facts in mind it seems evident that the loss in strength on heating is due to changes in the clay, either by decomposition of the crystal structure or by changes in surface conditions, and not due to changes in the sand particles or in the ferric hydrogel.

The work reported by Nevin[5] indicates that such a test may not bear a direct relation to the durability of the sand under actual working conditions. This may be due to the fact that in commercial work only a small part of the sand is actually heated in pouring and that durability may be as much due to quantity of bond as to quality. The tests reported in this paper certainly substantiate the claim that sands bonded by a ferruginous bond (ferric hydrogel) are less affected by heating than those not so bonded, as the bonding strength of clay bond is rapidly destroyed at 600 degrees Fahr. while ferric hydrogel bond is practically unaffected at this temperature.

[5] Trans. A. F. A., 33; (1925), p. 763.

Determining Returns From Materials Handling Equipment

By J. J. Hartley,* Chicago, Ill.

Various computations have been made showing that it is necessary to handle or rehandle from 150 to 200 tons of material to produce one ton of castings in the average foundry. It is therefore evident that materials handling is a major item of foundry cost and improved methods or short cuts which reduce this cost and tonnage ratio will result in lower cost of product.

"Continuous Process" Foundries

The most startling economies can and have been made in the shops doing repetitive work which we will call "continuous process" foundries. Some of them today closely approach the ultimate in which a molder does nothing but mold, a pourer nothing but pour, etc., etc., and the resulting straight line operations lend themselves admirably to low cost production through the installation of highly specialized handling devices.

Their problem of justifying the cost of an investment in materials handling equipment is comparatively easy, as the tremendous production attainable in these continuous units will rapidly "pay out" the most expensive special handling equipment.

This does not mean that such shops can select their materials

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handling equipment haphazardly. The utmost care and planning are essential to co-ordinate the equipment with other units and the production requirements of the plant. Every precaution must be taken to insure continuity of operation as a tie-up or breakdown of any part is costly and affects production schedules seriously. Again it may be said the returns from such installations justify a well organized maintenance force and the replacement of worn parts before breakdowns occur.

"Continuous process" foundries usually equip with mechanical handling devices from the receiving of their raw materials to the shipment of finished product and many of the savings effected are intangible unless determined over at least a year or more operations. We refer to such factors as:

1. Multiply value of floor space.
   Cut taxes, insurance, maintenance and depreciation of buildings per ton produced.
2. Better sand control.
   (a) Reduces labor cost of sand preparation.
   (b) Lower losses.
3. Lower inventories.
   (a) Cuts flask and pattern inventories materially.
   (b) High speed production lowers inventories of work in process.
4. Fewer accidents.
   Straight line operations and elimination of manual handling reduces accidents.

Please understand the above refers to intangible savings only, and we will not attempt to list out the tangible items for fear of getting into a discussion on the various types of equipment. Suffice it to say, it has been proved that a "continuous process" foundry under normal operations will save the cost of its materials handling equipment in a remarkably short time by the savings on direct and indirect labor alone, without regard to the above factors.

"Intermittent Process" Foundries

This latter class of foundries has cast longing eyes at the low cost production of the continuous shops, and in a few cases have tried to adapt this very specialized handling equipment to their conditions, sometimes with dire results. Others by proceeding with discretion and sound judgment have successfully ap-

Table 2

AMOUNT THAT MAY BE SPENT FOR EACH $1.00 PER TON REDUCTION IN COST, USING 20% PER YEAR FIXED CHARGES

Annual Earning in Percentage	Annual Production in Tons 1,000	2,000	3,000	5,000	10,000	20,000	30,000	40,000	50,000	60,000
100	$ 833	$1,660	$2,493	$ 4,165	$ 8,330	$16,660	$24,990	$ 33,320	$ 41,650	$ 49,980
50	1,428	2,856	4,284	7,140	14,280	28,560	42,840	57,120	71,400	85,680
33⅓	1,875	3,750	5,625	9,375	18,750	37,500	56,250	75,000	93,750	112,500
25	2,222	4,444	6,666	11,110	22,220	44,440	66,660	88,880	111,100	133,320
20	2,500	5,000	7,500	12,500	25,000	50,000	75,000	100,000	125,000	150,000

plied materials handling equipment to their intermittent processes and effected economies in handling raw materials, sand preparation, refuse disposal, casting handling, etc.

Flexibility of equipment is apparently the keynote for successful application of mechanical devices in such shops. In many cases these foundries serve outside interests and are subject to radical changes and wide variation in size and type of product. Their problem is therefore best solved by the use of standardized handling devices of the portable or semi-portable type.

Determining Returns

Practically the same principles should be applied to both the "Continuous" and "Intermittent" foundries to determine when it is profitable to invest in materials handling equipment.

Individual managements have widely different ideas on what may be considered an acceptable rate of return on capital investments and the following simple table is arranged to cover a rather wide range from 100 per cent down to 20 per cent annual return.

Disregarding any complicated accounting methods such as interest earned on depreciation reserve fund etc., and based on a 300 days operating year, allowing 20 per cent for fixed charges we have determined the amount it is practical to spend for each $1.00 per day earnings of the equipment as shown in Table 1.

For example, say there exists a condition in the handling of materials, which now requires three men, each earning $6.00 per day and by some rearrangement and the installation of a conveyor, crane, truck or other device costing $4,000 this operation could be made a one man proposition, thereby saving the pay of two men or $12.00 per day. This sum, minus the operating cost of say, $2.00 per day, gives a net earning of $10.00. From the table we find that a $10.00 per day saving will "pay out" a $4,280 investment in two years. To the average management with sufficient working capital such a proposition would be very attractive and would no doubt be approved—if—but and providing the party suggesting the plan will stake his reputation on the figures and the success of the idea.

Many proposed schemes are much more complex than the simple example given above, especially those involving a change from "Intermittent Process" to "Continuous Process." Such a transition requires the most careful analysis and time studies to determine the potential earnings and application to the particular conditions. Many times it is preferable to compute these potential returns on a tonnage basis to arrive at the yearly earnings. Table 2 has been found useful in determining the feasibility of installing materials handling equipment when the estimated reduction in cost per ton has been determined.

Table 1

Earning or saving per day	$ 1.00
One year or 100 per cent return	250.00
Two years or 50 per cent return	428.00
Three years or 33⅓ per cent return	562.00
Four years or 25 per cent return	666.00
Five years or 20 per cent return	750.00

From this table it may be readily determined that on a 10,000 ton yearly production a cut in cost of $5.00 per ton would justify an expenditure of $\$8{,}330 \times 5 = \$41{,}650$ for 100 per cent annual return or $\$14{,}280 \times 5 = \$71{,}400$ for 50 per cent annual return, etc.

Please understand these tables are presented, not as examples of correct accounting methods, but as a short cut for determining the possibilities of a proposed materials handling installation. For accurate and definite methods of computing the economies of labor saving equipment the Materials Handling Division of the A. S. M. E. have established formulas that may be recommended.

While it is usual to compute the potential savings on the reduction in direct and indirect labor costs alone, sometimes the so-called intangible items assume great importance and are entitled to major consideration. I have in mind one rather modest continuous unit that earned practically its entire cost the first year by the reduction in flask inventory.

It is apparent that the problem of applying materials handling equipment and determining its earnings involves; (a) common sense use of simple accounting methods; (b) co-ordination

of the plan with production requirements; (c) careful estimating entire cost of proposed equipment; (d) conservative estimate on returns, differentiating between the definite and intangible items, and last but quite important; (e) a wide awake management with the necessary working capital and courage to back the plan.

Effect of Various Elements on Malleable Cast Iron

By L. E. Gilmore,* Chicago, Ill.

Foreword

It has been well said that we cannot see the forest for the trees. We say this element hardens; that element softens; this one is a bad actor, and another is beneficial. And so it goes. It is all very good and essential to study the effect of each element, all other variables being constant. When we get right down to brass tacks, however, what we want to know is the resultant effect of these various elements in their combinations and reactions with each other on the finished product. How can we use the effect of one to neutralize that of another or the combination of two or more for a desired result. So it is well now and then to get together such information as we have and get a general view of the more important effects of various chemical elements and compounds on malleable cast iron.

*Crane Co.

Essential Condition of Carbon

In the production of good quality malleable, as we know it, we must cast the hard white iron with total carbon combined and then set free all this carbon by suitable heat treatment. Not only must the various elements be so combined and balanced that no free carbon is present in the white iron casting but the relationship must also be such that the carbon can be freed readily during the anneal. In addition to such control the strength and ductility of the iron is also dependent on the total quantity of certain elements present, notably the carbon.

In the ordinary malleable iron of commerce there are present six elements; iron, phosphorus, manganese, sulphur, silicon and carbon. Other elements may be present by accident, or with design to produce or accentuate a particular effect.

Iron, a very soft and ductile metal, is the base of the alloy and constitutes from 95 to 97 per cent of malleable.

Effect of Phosphorus

Phosphorus is usually between 0.10 and 0.20 per cent and seldom exceeds 0.20 per cent in commercial malleable. Phosphorus about 0.25 per cent is no longer entirely soluble in the ferrite of the finished product.[1] Up to this amount there is no effect on graphitization but a direct effect on physical properties. Phosphorus up to about 0.20 to 0.25 per cent strengthens the metal without decreasing its ductility.[2] As about 0.25 to 0.31 per cent phosphorus, depending upon the amount of carbon present, produces free phosphide, the effect of higher phosphorus is to cause some brittleness and less strength.[3] Phosphorus in solution in iron is harmless. Free iron phosphide does the damage.

Manganese Sulphur Ratio

The very important and chief function of manganese in malleable iron is to combine all the sulphur present in the form of

[1] H. A. Schwartz, *American Malleable Cast Iron*, p. 59. The Penton Publishing Co. 1922.
[2] H. A. Schwartz, *American Malleable Cast Iron*, p. 292. The Penton Publishing Co. 1922.
[3] W. H. Hatfield, *Cast Iron in the Light of Recent Research*, p. 51. Charles Griffin & Co., Ltd., London. 1912.

manganese sulphide. Abnormally large amounts of sulphur are practically harmless if the manganese sulphur ratio is maintained.[4] Some slight excess of manganese is required. Manganese sulphide is neutral. Any excess sulphur present over manganese sulphide forms iron sulphide and retains about 0.80 per cent carbon combined even after the most drastic anneal. A very large excess manganese of the order of 0.8 per cent excess is required to produce this same effect on malleable.[5] The excess manganese forms double carbides with iron and carbon and will retain part of the carbon combined after anneal, when present in large amounts. When manganese and sulphur neutralize each other they practically have no effect on the physical properties of the finished iron.

Silicon Carbon Balance

With phosphorus, manganese and sulphur in normal proportions the silicon carbon balance determines the physical properties of malleable. For the sake of simplicity we assume fixed conditions of casting temperature and of the variables that might affect the rate of cooling. In normal foundry practice these variables which have very important effects on the condition of carbon in white iron become standardized and may be regarded as constants for the purposes of this discussion.

Any primary graphite in the white iron casting greatly weakens the final product. To avoid this, the higher the percentage of carbon the lower the silicon must be, or vice versa. Silicon is a well known promotor of graphitization both in iron as cast or during anneal. Its ability as a "promoter" is dependent upon the relative proportion of carbon and silicon.

Combined carbon, except in minute amounts, in the finished annealed iron is undesirable, for although it may increase tensile strength, it greatly reduces ductility.

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[4] L. E. Gilmore, *Proper Sulphur Manganese Ratio Must Be Maintained*, Vol. 55, p. 734, The Foundry, Sept. 15, 1927.

[5] Unpublished experiment by the author.

Low Carbon with High Silicon Makes Strongest and Most Ductile Iron

The lower the percentage of carbon the greater the strength and ductility. Carbon 1.7 per cent is about the minimum which can be readily precipitated in commercial annealing, so it is well to aim for carbon well above this figure. Carbon 2.20 to 2.30 per cent in a standard ⅝ inch diameter test bar will give 20 to 25 per cent elongation in two inches, with tensile strength from 54,000 to 57,000 pounds per square inch. Within a limit of silicon low enough to cause no precipitation of graphite in white iron, silicon has no effect on elongation. An increase of silicon from .70 to .90 per cent with carbon constant about 2.25 per cent will increase the tensile strength 2,000 to 3,000 pounds per square inch.

With increasing carbon, ductility becomes less and less with a corresponding loss in tensile strength. The combination of greatest strength and ductility is a low percentage of carbon with high silicon.

So much for the effect of the usual elements found in malleable. Probably every producer of malleable castings at one time or another has experimented with the addition of various elements to his iron in furnace or ladle. In general, it may be stated that if the usual elements found in malleable are properly balanced, then the addition in any quantity of other elements will upset the balance. The result of this unbalancing may become evident either by causing precipitation of graphite in the hard iron or by retarding or accelerating the precipitation of temper carbon during the anneal.

Those elements which with increase have the power progressively to throw out primary graphite have also the power to help release combined carbon during the anneal. On the other hand, those elements which tend to hold carbon combined in the white iron have similar effect in retarding the anneal.

Aids to Graphitization

If silicon is present just under that which would cause separation of primary graphite, the addition of any other "precipitator" element would be additive to the silicon and make the iron

more or less gray. In general, these elements go into solid solution in iron thus leaving less iron to hold the carbon which then precipitates. Such elements can be used to replace the silicon in whole or in part and when used in quantities to maintain proper balance with the carbon, normal malleable iron may be produced. Aside from silicon, aluminum is the most commonly known precipitator of carbon. Titanium, nickel, uranium and zirconium act in a similar manner. In iron containing practically no silicon, 0.10 to 0.15 per cent titanium or aluminum or .50 per cent zirconium prove effective substitutes.[6] Calcium silicide is used to make a gray iron from white iron.[7]

Inhibitors of Graphitization

Inhibitors of annealing, which also tend to hold carbon combined in white iron, are in general elements which form carbides or double carbides when present with iron and carbon. Of course the absence of silicon or like "precipitators" may inhibit graphitization. Abnormal amounts of sulphur or manganese as already noted will act to the same effect. Other inhibitors are antimony, boron, cerium, chromium, molybdenum, selenium, tellurium and tin.[8] For instance, about .25 per cent chromium added to normal malleable is effective in holding a pearlitic matrix (about .80 per cent combined carbon), after anneal. Vanadium acts in a manner similar to chromium in assisting carbon to remain combined.[9]

In the final analysis, malleable iron should be thought of not so much as an alloy in which each element has a fixed and individual function but more as a mixture of compounds and interacting elements which, when properly balanced with each other, will produce the highest quality iron. It is the manner in which the elements unite in compounds and the relative propor-

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[6] H. A. Schwartz, U. S. Patent 1,636,657, July 19, 1927, and U. S. Patent 1,640,674, August 30, 1927.

[7] Augustus F. Meehan, U. S. Patent 1,499,068, June 24, 1924.

[8] H. A. Schwartz and G. M. Guiler, *Chemical Elements Inhibiting Graphitization*, Vol. XXXIII, p. 639, Trans. of the American Foundrymen's Association, 1925.

[9] W. H. Hatfield, *Cast Iron in the Light of Recent Research*, p. 87. Charles Griffin & Co., Ltd., London. 1912.

tions of certain elements as well as the total percentage of any one element that determines the degree of success in producing good malleable castings.

Theory or Practice in Gray Iron Foundry

By John Shaw, Southsea, England

Part I

Certain inspired references to the ignorance and want of initiative in research on the part of the practical iron founder has led us to put up to you for plain discussion, points that have some bearing on the question. To quote from one of the mildest of these critics, we are told that "much border line work could be captured from steel by the commoner material if the iron founder would follow the example set by the progressive steel founder," that to succeed led inevitably to the laborious synthetic method, etc. Now is this indictment a true one, and, if so, why?

In the first place a mild steel casting is a very simple metallurgical problem (we are not referring to molding and other difficulties) and consists of only two elements that matter, iron and carbon, the others being either "cleansers" or in the case of sulphur and phosphorus kept as low as possible. Under these conditions one can understand the utility of the binary or ternary diagrams, especially in view of the after heat treatment. Complex cast iron, on the other hand, is influenced by all six elements, each having considerable bearing on the final product. The history of steel also reveals the fact that it was not possible to make sound steel until the accidental discovery of the deoxidizing effect of manganese. Unfortunately, in some respects, fairly good cast iron can

be obtained by simply mixing pig and scrap in any corner cupola, hence the lack of apparent need for research, combined with the fact that the price paid has left no margin.

A glance at the analyses of a typical mild steel casting, and a cylinder iron (Table 1) shows that their only similarity consists in that both contain the same elements, but in totally different proportions.

Table 1

COMPARATIVE ANALYSIS OF A TYPICAL MILD STEEL CASTING AND A CYLINDER IRON

	Per Cent Total Carbon	Per Cent Silicon	Per Cent Manganese	Per Cent Sulphur	Per Cent Phos.
Steel Specification	0.2 to 0.4	0.26	0.6	0.04	0.04
Cylinder Iron	3.0	1.2	0.8	0.12	0.3 to 0.8

In view of the above analyses, has not the attempt to apply to cast iron the theories evolved in the case of steel been a hindrance to progress, rather than a help? The statement that cast iron is simply a steel interspersed with graphite may be useful to the teaching profession, but there is no doubt it has not helped to a better understanding of complex cast iron. In short, is the synthetic method of approach that was successful in steel, the best for cast iron?

Many research workers have tackled cast iron by choosing some particularly pure white iron, with the result that much literature exists concerning metal of such qualities and compositions as are met with in no foundry in the world.

To take only one instance, it is nearly 20 years since Gonterman published his work on the effect of silicon. Last year we had a most carefully prepared paper by Dr. Hanson on the same subject, putting forward a new theory that might reconcile the divergent views as to the primary graphitizing point. At the same time, valuable as this contribution was, especially on the scientific side, it has added little to our knowledge of the ultimate structure that was not previously known. As the author states, the other elements in cast iron may alter the results, and also in cooling, equilibrium may seldom be reached. All the recent advance in cast iron has been founded on a cast iron base, having all the elements present in such quantities as are found in cupola work

of which the work by Lanz, Emmel, and Donaldson are examples.

If we take the elements in rotation as found in the two previous analyses, we find the total carbon of the steel casting limited to 0.2 per cent to 0.4 per cent. Up to this limit, according to Charpy, no graphite is formed at any temperature in the presence of even 2 per cent silicon. In cast iron your carbon may be anything from 2.5 per cent to 3.5 per cent, and every element, melting temperature and mold temperature has an effect on the final product. Even if your composition gives you a pearlitic structure, the tensile strength may vary from 9 tons to 17 tons (20,160 to 38,080 lbs.), due entirely to the form and quantity of the graphite and the variation in the type of pearlite.

Silicon Effects

The silicon in mild steel castings is about 0.2 per cent. Its function is to act as a cleanser and give rather better running qualities. In cast iron silicon is one of the dominating elements, and its influence on the condition of the carbon has much to do with the physical properties of the resultant casting.

It is 40 years since Professor Turner's famous investigation on the effect of silicon on cast iron was completed. Turner states that the interest taken in cast iron at that time and during the next few years was truly remarkable and was not confined to any single country. Without in any way diminishing the value of this discovery, there is no doubt that the abuse of the use of silicon has done not a little to lower the physical properties of cast iron. A quotation from Keep's paper before the Philadelphian Foundrymen will show what I mean: "Silicon is the only thing necessary to the foundry, all other things in cast iron can be overlooked. If the shrinkage is not low enough—if the iron is too hard or not gray enough, add silicon, it remedies all other defects. It is the only variable to consider, and it is the easiest to manage." While this quotation is extreme, there is no doubt that in the craze for fast machining on one hand, and the softening of cheap materials, irrespective of their composition, silicon additions are still used to the detriment of the physical properties.

With the advent of the Institute of British Foundrymen, fresh interest was created in the various problems.

The personal interest of Professor Turner in this movement led to the remarkable series of investigations undertaken at Birmingham University. Those of Levi, Coe, and Hague are quoted today. Hatfield, who at that time was interested in malleable, also did some good work. Hague presented a paper before the I. J. S. I. on the influence of silicon on pure cast iron in October, 1910, while Coe, following other papers, dealt with the physical properties in 1913. Broadly speaking, the results agree, that is, with the separation of graphite, due to the effect of silicon, the strength and hardness of the bars decrease.

One of the points that seems to have been overlooked was the effect of comparatively wide variations in carbon. The chief object in using a synthetic mixture was to be sure that there should only be one variable, yet in all these experiments the carbon varied between 2.26 per cent and 2.95 per cent, a difference of 0.69 per cent. This would make a considerable difference on the final structure and strength of the unannealed bars.

An examination of any published chart of blackheart malleable giving depth of chill in relation to carbon and silicon content, shows that with silicon below 0.7 per cent, two parts of carbon will have the same effect as one part of silicon on the depth of chill. With the silicon from 0.7 per cent to 1.2 per cent, four parts of carbon are equal in effect to three points of silicon. As the chill disappears at the higher silicon this is as far as our definite knowledge goes; we also know quite definitely that the addition of 0.06 per cent silicon to an analysis just mentioned will decrease the depth of the chill ¼ inch, so roughly the effect of carbon on the structure can be calculated.

Since the war the formation of the British Cast Iron Research Association has led to fresh interest in cast iron problems, of which the paper mentioned, by Dr. Hanson, is one result.

We have purposely not gone into details concerning the various investigations, because of the ground we wish to cover,

but anyone interested will find the whole question dealt with, either in Turner's, Hatfield's, or Hurst's books. Table 2 gives roughly the results of the various workers, the size of the bars and method of casting varied so that the results are not very helpful, although the influence of silicon is shown.

The data of Table 2 raises the whole question of the suitability of using small bars to obtain results on which are based such diagrams as Maurer's. A one inch square or 1¼ inch diameter bar presents so much superficial surface in relation to its cubical content that the quick cooling rate masks large variation

Table 2

	Hatfield	Hamasumi 1st Series	Hamasumi 2nd Series	Hague	Coe		
Per Cent Total Carbon	3.07 to 2.95	3.35 to 3.33	2.90 to 2.93	2.47 to 2.95	2.88	3.04	3.22
Per Cent Combin'd Carbon	0.6 to 2.3	0.66 to 0.90	0.63 to 1.13	0.97 to 2.82	1.08	1.27	3.19
Per Cent Silicon..	1.72 to 1.68	2.90 to 1.18	2.90 to 0.64	1.95 to 0.66	2.03	0.80	0.4
Tensile Strength, Tons (2240 lbs.)	12.7 to 11.41	7.44 to 10.07	16.5 to 18.4	......	13.72	10.06	14.33
Size of Bar.....	1" x ⅜"	1¼" round	......	1" square	1 inch square		

Table 3

T. C.	C. C.	G. C.	Si	Mn	Phos.	Sulphur	Total Carbon and Silicon	Brinell
%	%	%	%	%	%	%	%	
2.7	0.91	1.79	1.36	0.77	0.50	0.09	4.06	161
3.81	0.87	2.94	1.44	1.23	0.06	0.06	5.25	106

in composition, of which the data of Table 3 taken from the figures in the latest Maurer diagram are samples, yet these showed all pearlitic structures.

Manganese

This element in mild steel castings is useful as a deoxidizer, to neutralize the effect of sulphur, and also to increase the yield point and ductility.

In gray iron, investigations have been made by Stead, Coe, Wust and others. The position at present is best summed up by Hamasumi; first, that manganese up to 2 per cent in the presence of silicon as in gray iron, does not retain carbon in the combined form and second, that with the increase of manganese the pearlitic structure is considerably altered and tends to be sorbitic.

Hence the increased Brinell hardness with no increase of combined carbon; with more than 0.5 per cent the tendency is for the graphite to be in "Whirl" form. Manganese also improves fluidity and tends to a sound casting.

There is so large an amount of evidence on the first point that one wonders at the often repeated statement, that manganese after satisfying any sulphur present, hardens cast iron in the proportions usually found. Outerbridge stated that this is a mistaken notion and gives proof. A glance at Coe's or Hamasumi's tables also confirm. Dr. Howe, discussing Hatfield's paper, states "The influence of manganese in increasing the stability of the carbide is opposed by some additional fact, as has so often been noticed. For instance, Mr. Hatfield's S33 and S23 are closely comparable except manganese, and so are S34 and S24. After heating to 950 degrees Cent., the higher manganese specimen in both cases graphitize more than the lower manganese ones."

Wust and Miny in their paper on sulphur in cast iron say "Sulphur counteracts the graphitizing effect of manganese."

Coe in a later paper on the influence of metalloids on properties of cast iron, replying to the discussion states "The experiment performed by Hague on the influence of 0.5 per cent manganese has been repeated under the same conditions, and also under very different conditions, always with the same results; so that it may be definitely stated that in siliceous cast irons with the ordinary rate of cooling, the addition of the first 0.5 per cent manganese results in a softening, owing to the precipitation of secondary graphite.

Allison, in a paper on chilled rolls, states "Ferro-manganese was added in the ladle in several instances, but it was found that thereby the amount of chill is seriously affected. What appears to be a critical point is a percentage of 0.36 per cent manganese and it was found undesirable to have the manganese content any higher."

Table 4 gives the results of the various workers, with a minimum of sulphur present.

Whether this graphitizing action of manganese is a direct

Table 4

	Total Carbon	Combined Carbon	Silicon	Manganese	Sulphur	Phos.	Pounds Transverse Strength Bar 12"x1"x1"	Deflection in Inches	Tensile Strength Tons (2240 lbs.) per Square Inch
Coe	3.28	1.13	1.0	0.014	Trace	0.09	2732	0.094	12.67
Coe	3.15	0.82	1.02	0.846	Trace	0.09	3461	0.092	16.59
Coe	3.02	0.92	1.62	0.04	0.015	0.093	2665	0.132	10.10
Coe	3.04	0.43	1.50	1.03	0.015	0.093	3035	0.11	15.11
Coe	2.79	1.06	2.24	0.016	0.016	0.027	2240	0.08	9.92
Coe	3.03	0.69	2.42	1.96	0.016	0.027	3203	0.12	15.47
Hague and Turner	2.77	0.84	3.06	Trace	Trace	Trace	....	...	...
Hague and Turner	2.62	0.22	3.00	0.50	Trace	Trace	....	...	...
Hamasumi	2.90	0.82	1.65	0.15	0.02	0.01	....	...	16.8
Hamasumi	2.89	0.76	1.72	0.30	0.02	0.01	....	...	18.7
Hamasumi	2.96	0.86	1.61	0.69	0.02	0.01	....	...	19.9
Hamasumi	3.04	1.07	1.71	1.34	0.02	0.01	....	...	22.3
Hamasumi	2.84	0.77	1.85	3.94	0.02	0.01	....	...	26.3

one or, whether it is simply due to the considerable lowering of the pearlite point we leave to abler metallurgists. The latter combined with the shorter freezing range would account for the finer graphite usually found and also for the higher Brinell number without affecting the machining speed. The latter theory would also offer an explanation for the necessary time element noticed with the graphitizing effect of manganese. For instance, Cook found if he raised his manganese above 0.4 per cent he was liable to machining trouble in the bore of his cylinders. As his main body core was chilled lined, the cooling rate would be too quick to allow the secondary action of the manganese. Our experience (Table 5), with certain rolls, points the same way. This we attributed to the excess ratio of manganese to sulphur.

Table 5

T. C.	C. C.	Si	Mn	Sulphur	Phos.	Depth of Chill on Test Piece	Depth of Chill on Roll	Loss	Mn to Sulphur Ratio
2.96	0.55	0.5	0.42	0.089	0.45	2⅛"	¾"	1⅜"	4 to 1
3.16	1.37	0.83	0.27	0.164	0.5	1⅜"	⅞"	½"	1.5 to 1

Table 6

	Total Carbon	Combined Carbon	Silicon	Manganese	Sulphur	Phos.
A	3.34	1.44	0.90	0.25	0.136	0.39
B	2.98	0.65	0.71	0.49	0.120	0.31

The chill test in the first shows 2⅛ inches, while the roll only shows ¾ inch, a loss between the chill test and the roll of 1⅜ inches. The second roll only showed a variation of ½ inch.

Loudenbeck in a paper before the American Foundrymen's Association gave a number of instances: "In the manufacture of large hydraulic cylinders it is necessary to have a close mottled structure to withstand breakage and prevent leakage. If the manganese is too high this mottled structure is replaced by a coarse graphitic structure. This is illustrated by two analyses. The bodies were 6 inches thick, *A* (Table 6) was a close mottled structure that gave very satisfactory results in all the 20 cylinders required; *B* analyses gave a fracture open and not mottled and the cylinder was not satisfactory. Manganese was too high in the defective cylinder which accounts for the low combined car-

bon and soft character of the mixture. Without doubt this cylinder would have been satisfactory if the manganese had been lower."

From the report in Genie Civil on ingot molds, it would appear there are two critical percentages of manganese to stand up to heat treatment. The usual specification was to limit ingot molds to 0.6 per cent. M. Groselaude found he obtained a rise in the number of casts made, up to this figure of 0.6 per cent with a maximum of 110 casts, then there was a sudden drop to below 20 casts with manganese at 0.8 per cent. This low figure continued until about 1.6 per cent manganese was present with an average of 140 casts. With manganese 1.75 to 2.25 per cent the average over two years was 175 casts. With further increases, the number of casts dropped rapidly.

Smalley's results on "Heat and Scale Resisting Cast Irons" might be quoted, although as these were white irons, they are rather outside the subject. His conclusions were that manganese,

1. Reduces the resistance to scaling,
2. Increases graphitization.
3. Decreases strength and should not exceed .30 per cent.

We have put these examples forward because of the excellent results obtained by Carpenter, Matsuura and Donaldson with high manganese irons showing special resistance to growth and giving good physical properties up to 500 degrees Cent.

As all these results were obtained on small bars, it might be advisable to try out the behavior on thicker sections, such as are found in Diesel liners.

Sulphur

Before touching the manganese sulphide question, it would be well to consider the effect of sulphur. That sulphur is injurious to steel as FeS is accepted at once, the great variation in the freezing point leading to the well-known structure, but in cast iron even with manganese as low as 0.2 per cent and sulphur as high as 0.2 per cent (which is as low and high as ever found in ordinary cast iron) no clear proof has ever been submitted showing the evil effect of FeS as such. Coe states "The transverse strength, tenacity and hardness are increased by the addi-

tion of sulphur." Wust and Miny state "The tensile and transverse strengths and resistance to impact of low manganese irons are not impaired by sulphur"; "In all cases the hardness is increased by the addition of sulphur independently of whether it is present as FeS or MnS." Rhead, Cook, and Hamasumi also agree. Rowe states "Experience has shown that it is extremely difficult to get iron of high strength with abnormally low sulphur." Neither Cook, Coe, or Hamasumi, found any difficulty with fluidity if cast at a high temperature. The latter named found the tensile was 1.3 to 2.5 tons (2512 to 5600 lbs.) higher when cast at 1400 degrees Cent., instead of 1350 degrees Cent. Neither has the author experienced any difficulty in running metal with S, 0.25 per cent; Mn 0.35 per cent; not so much as with carbon down to 2.5 per cent. Table 7 gives some of the results.

In view of the above facts it is difficult to account for the oft-made statement concerning the cause of the weakening effect of FeS *as such,* in the amount found in gray iron. Is this not another effect of steel theories? Personally we have never seen FeS in any iron with 0.2 per cent S and 0.2 per cent Mn, neither have we ever met anyone who could produce a photo or sample showing FeS with sulphur below .2 per cent; certainly not as a band surrounding the crystalline structure as in steel.

Bolton in a paper before the American Foundrymen's Association states, "In the author's experience he has never been able to find any evidence of sulphur network, and the idea that fracture depends on sulphur network is a myth."

From what has been said we may conclude that sulphur in cast iron is only harmful when it is present in such amount as to give you an excessive quantity of free cementite or when other elements such as silicon have to be increased to neutralize this affect and reduce your combined carbon to a reasonable figure; otherwise sulphur under control, is of great value as a strengthener and grain refiner.

If from any cause such as heavy steel additions, such as are used in "Emmel" or "Meehanite," you are nearly forced to have a high sulphur, there are two ways to reduce your combined carbon. First, to increase your silicon or both carbon and silicon,

Table 7

	Total Carbon	Combined Carbon	Silicon	Manganese	Sulphur	Phos.	Trans. Strength Pounds on Bar 12"x1"x1"	Deflection in Inches	Tensile Strength Tons (2240 lbs.) per Square Inch	Shore Hardness No.
Coe	2.79	1.06	2.24	0.016	0.016	0.027	2240	0.080	9.92	45
Coe	2.90	1.06	2.24	0.016	0.104	0.027	3125	0.114	13.04	45
Coe	2.70	1.13	2.37	0.016	0.180	0.027	3994	0.150	21.2	43
Hamasumi	2.90	0.79	1.77	0.02	0.049	0.01	....	....	21.4	*210
Hamasumi	2.84	0.74	1.76	0.02	0.087	0.01	....	....	23.0	*223
Hamasumi	2.85	0.81	1.82	0.02	0.120	0.01	....	....	22.9	*226
Hamasumi	2.80	1.04	1.87	0.02	0.176	0.01	....	....	21.5	*241

*Brinell Hardness No.

in which case you gain little strength, owing to your coarser primary graphite and pearlite, also your resistance to growth at moderate temperatures is decreased. Or, increase your manganese thereby rendering part of your sulphur passive as MnS, while the excess manganese acts as a degasifier, grain refiner, and gives life as shown previously.

Manganese Sulphide

It is also difficult to understand the oft-made statement that with a ratio of even of seven of manganese to one of sulphur that the whole of the sulphur is in the MnS condition. How is it that even with this ratio, if you increase the sulphur in your charge, leaving the other elements the same, your resultant castings are harder and the combined carbon higher? The same effect takes place if you increase your sulphur by adding it down the spout of the air furnace. The resultant rolls will be deeper in chill. There are thousand of tons cast under these very conditions and as some take five to six hours to set, if you tell me equilibrium conditions have not been attained, we are not interested, as it is evident they never would be under ordinary foundry conditions.

There is no doubt that sulphur exists additionally to MnS in association with the carbides either in solution or as a ternary eutectic. With regard to MnS (a weak brittle material, rotten as a carrot, Stead calls it), its addition can only be considered as the lesser of two evils. Fortunately its volume is never large, but being non-soluble in molten iron, it may segregate in important spots and cause damage out of all proportion to its volume.

Young, speaking of manganese-sulphur balance, states "Certain Diesel cylinder liners came to a most disastrous ending through that very cause, the failure being a mystery to everyone, until the unbalanced sulphur and its effect were discovered." Coming from such a source, it is a pity Mr. Young did not take us more fully into his confidence, giving both analyses, micros, and his interpretation of same; for the result would have been of great value to many. Unfortunately most of us are obsessed with one idea and sometimes fail to see the other points, as we shall probably learn tonight. The series of analyses (Table 8) given by

Table 8

Total Carbon	Silicon	Phos.	Sulphur	Manganese	Mn to Sulphur Ratio	Pounds Trans. Strength on Bar 12"x1"x1"
3.45	1.62	1.08	0.122	0.27	2.2 to 1	1747
3.43	1.47	0.60	0.231	0.23	1.0 to 1	2341
3.37	1.56	1.21	0.137	0.28	2.0 to 1	2352
3.47	1.47	0.61	0.220	0.41	1.9 to 1	3528
3.38	1.73	1.14	0.112	0.58	5.2 to 1	3662
3.41	1.05	1.05	0.129	0.51	4.0 to 1	3786

Young are not too convincing, but as the combined carbon is left out, it is hard to come to any conclusion. It could be held the last two gained strength from the excess manganese. He also states in the same paper, "It is possible, even probable, that sulphur and manganese, together, are the most vital combination in cast iron."

Unreliability of Evolution Method of Sulphur

Before leaving the sulphur question it would be well to give another warning concerning the unreliability of the evolution method with moderately high sulphur. We could seldom obtain check results by the two methods, nor could several outside firms when asked to check our results.

Recently Crome tested 40 samples by both evolution and oxidation methods. In ten cases, both methods gave near results. In 19 the results varied 50 per cent, the remaining 17 fell between the two extremes. Stating there was a popular idea that by annealing, the correct result would be obtained by the evolution method, he tested 15 samples after annealing, by both methods. The results were remarkably close, but instead of agreeing with the original oxidation value, they checked with the original evolution result. An amount of sulphur equal to the original difference had been lost. Whether this fact has anything to do with the difference in the behavior of the MnS and FeS in the Baumann test, might be investigated.

Crome states, "In spite of the same period of reaction, the same acid concentration, and conditions otherwise equal, and particularly the same sulphur content, prints were colored much darker by the MnS than the FeS; obviously the solubility of MnS in acid, is greater than FeS."

Phosphorus

Phosphorus is definitely known to be injurious to steel, but its effect on cast iron is not so clear. Stead, Hatfield, and others have investigated the ternary alloy iron-carbon-phosphorus and there is a fair knowledge to this extent, but no work has been done with the remaining elements added, except some experiments by the Japanese with silicon present.

The whole trend of modern work has been to limit the phosphorus to about 0.3 per cent, the limit of solid solubility. On the other hand, from a list I have taken from all sources, there is no doubt high tensile results are obtained with, up to 1 per cent phosphorus.

Both Lowry and Piwowarsky say that phosphorus shows an increased resistance to wear with increasing phosphorus up to 0.9 per cent, while Lehmann from service conditions on brake blocks, comes to the conclusion that phosphide eutectic has a harmful influence on the wear, as it tends to form a grinding substance. Young also found that "Corrosion by sea water is hastened by increase of phosphorus." From our experience, over a period of 15 years with about 50 tests per week, it was proved that with

Table 9

T.C.	C.C.	Si	Sulphur	Mn	Phos.	Pounds Transverse Strength	Tensile Strength Tons (2240 lbs.)	Brinell Hardness No.
3.05	0.75	1.27	0.07	0.47	0.75	3767	15.2	228
3.08	0.63	1.41	0.10	0.43	1.04	3472	15.5	228
3.06	0.76	1.30	0.12	0.30	1.30	3136	15.4	228

increase of phosphorus the relation between the transverse and tensile altered, the transverse and deflection result dropping with increase of phosphorus. This was confirmed by Field, Hyde, and others, and also by the list of collected analyses. One of Wheeler's is given as an example in Table 9.

The best paper for some years was one by MacKenzie, the result of several years work and comprising some thousands of tests. The discussion which follows was equally important because it touched the vital issues. MacKenzie's conclusions are "That for each type of casting the maximum strength will be found at the lowest phosphorus content compatible with fluidity. For cast-

ings where resistance to shock is of importance, low phosphorus irons should be used, but ordinarily no trouble will be experienced with phosphorus running up to 0.8 per cent if the carbon and silicon are correctly proportioned to give the strength desired."

Smalley took exception to the last point, stating that between 0.25 and 0.8 per cent of phosphorus is a very delicate and dangerous region of phosphorus in producing differential freezing, and where there is a change of section and the formation of phosphides is thrown out, it tends to cause porosity and spongy places. This is in line with Harley's and other Coventry managers' experiences.

Bolton also pointed out that in gray iron, metallurgists assumed that "the eutectic form was the only one occurring in cast iron; that was not so, you have in the lower phosphorus irons, a solid solution *steadite.* It is not a eutectic alloy in any sense of the word and can be shown microscopically. It is not until you have about 0.5 per cent phosphorus in cast irons that are fairly high in pearlite that you get the eutectic alloy."

Cupola Practice

Having dealt with the chemical composition there are two other variables that do not affect steel to the same extent; first, cupola practice. Perhaps the exhaustive trials carried out by Rudeloff for the German Ironfounders, illustrates this. The object was to ascertain with what degree of certainty similar physical properties could be obtained in a number of foundries using the same prescribed material and working on the same lines. Specialists of acknowledged standing supervised each cast. Despite the use of the same mixture, the results varied widely, transverse figures ranging from 21.5 to 27.5 tons (48,160 to 61,600 lbs.), while the tensile gave values from 10.75 tons (24,000 lbs.) to about 15 tons (33,600 lbs.) per square inch. Next, each foundry was to aim at a transverse of 17.8 tons (39,872 lbs.) with a deflection of .28 inches and an upper limit of 21.6 tons (48,384 lbs.) with a deflection of .39 inches with their own mixtures. Here again there were wide fluctuations, the range being 21.5 to 31.3 tons (48,160 to 70,120 lbs.) and from 11.5 to 16 tons (25,760 to 35,840 lbs.). It is difficult to account for these variations under

the fixed conditions and we, in this country, work nearer.

Melting Temperature

After the investigations of Elliott, Piwowarsky, Kerpely, Emmil, and lately Homma, there is no doubt that high melting temperature has a great effect on the resultant metal. You are familiar with Piwowarsky's results—Homma's confirm these. He made a series of experiments and found that with increased melting and casting temperature, he increased both depth of chill and hardness. He then carried out further trials, taking the metal up to 1500 degrees Cent., then lowered it to various temperatures and poured, thus by keeping the maximum temperature constant and then varying the casting temperature, he showed there is very little change in hardness or depth of chill, so casting temperature may not be the vital matter we think, and the variation in several investigator's results may be due to neglecting to note the tapping or melting temperatures.

There is another side to this issue. We, who have charge of a foundry, all know that to cast cold leads to hard castings. For instance, Evans of Derby noted that in casting a number of cylinders from one ladle, if there was a complaint from the machine shop regarding hardness of one or two cylinders in that batch, it was nearly in every case the last one or two cast. This is easily explained, being due to the chilling effect of the mold. In going through figures for this paper, we have noted more than one investigation, where the given casting temperature was below the liquidus. Those crystals and others formed inside the mold, will never go into solution again and it is futile to expect reliable results under these conditions.

Exhaustive Study a Great Undertaking

The question naturally arises, how is it no serious attempt has been made to study the effect of each element on a base material containing the other elements in the lowest proportions found in cupola metal? The simple fact is the investigation is too large for any one university to undertake. After all, their object is to educate; any special research, can only be undertaken by post graduate students or those who who receive a special grant. Even

the British Cast Iron Research Association could not hope to undertake it without exhausting both the patience and the interest of its members. The position is best summed up by the late Professor Jeremy Porter: "If each of the six elements is varied in only seven proportions, and each resultant metal tested by each of the twenty physical properties, 2,352,980 different experiments would be required."

At the same time it might be possible with the aid of the universities situated in gray iron centers (Birmingham, Sheffield, Manchester, Newcastle, and Glasgow) together with the help and supervision of the British Cast Iron Research Association to tackle

Table 10

	Total Carbon	Silicon	Manganese	Sulphur	Phos.
Suggested Base Material	2.5	0.5	0.5	0.03	0.3
Suggested Increases	3.0	1.0	0.8	0.08	0.8
	3.5	1.5	1.1	0.11	1.1

the problem in a modified form. There is no difficulty in obtaining an iron containing the lowest content of each element found in any casting. This would not vary from end to end of the pig bed by anything like the amount given in several of the investigations using a synthetic base (Table 10).

Cast Irons Cover Wide Range of Combinations

If each element is varied in three proportions, as shown, this would cover nearly all the high test irons. The low silicon and low carbon combinations would require to be cast in heated molds. Even this modified program would entail 1944 different mixtures. How many physical properties to be considered could be arranged, but cooling curves would be useful. The melting and casting temperatures are vital and could be fixed at 10 per cent and 5 per cent, respectively, above Dr. Hanson's liquidus curve for the corresponding silicon content.

The question of how the increases of each element are to be made, is important. The addition of high percentage ferro-silicon or ferro-manganese direct to the melt under investigation is too drastic and masks any lag or inertia of dissociation usually found. Adamson before the I. F. S. I. stated, "It was well known that

the addition of high grade ferro-silicon to white or mottled iron produces, and in close gray iron retains, the graphite in its most finely divided state, and thus gives a much closer grained iron than if the same silicon content were obtained from melting a high silicon pig iron." Our air furnace practice confirms this, viz:—that for the same depth of chill from ladle sample, the silicon content is often four points higher if softening of bath has been made with ferro-silicon instead of silicon pig.

The same thing applies if you increase your manganese by additions down the spout, to cupola metal. Campion says, "The same results were not attained by additions of manganese down the spout." This also confirms our experience over a number of years.

You obtain a loss of sulphur by adding manganese down the spout if you hold the metal some time, but never find much loss in the ladle even if the Mn to S ratio is higher, as charged. We had about a 10 per cent loss of chrome when charged into the furnace as ferro-chrome, but on remelting the resultant metal in the cupola, no further loss took place.

These examples could be multiplied. Homma, using a .08 per cent silicon Swedish pig, on drastically lifting the silicon to 1.98 per cent, found that this metal always gave a deeper chill and hardness (as much as 50 per cent) than another iron that had not been so drastically treated, although the former, as used, was higher in both carbon and silicon, viz:—3.75 per cent carbon and 1.98 per cent silicon in the first case, while the latter had only 3.48 per cent carbon and 1.67 per cent silicon.

The best method to make additions of any one element to an investigation was the one used by Dr. Hanson, where from the standard base metal he made a special alloy containing fairly large percentages of the element, say 10 per cent in the case of Si, Mn and P, with one per cent for sulphur. With carbon, the difficulty would be to obtain even the 6.8 per cent found in Dr. Hanson's case, but it might be possible to reach 4.5 per cent carbon without unduly oxidizing the silicon and manganese in the base metal. Then a 50-50 mix would give you the highest carbon required in the investigation. Roughly, 10 per cent of the other

alloys containing silicon, manganese, phosphorus or sulphur as the case might be, would give you the maximum required. Additions, made in this manner would allow for the usual reactions found in ordinary work. The remaining points are equally important, viz:—fix the size or sizes of the test pieces and the size of the box the test pieces are to be molded and cast in. If cooling curves of the sand are to be taken, the position of the end of the pyrometer in relation to the casting is to be given.

Investigations of Effect of Size of Bar

With a 1.2 inch bar it is possible to obtain an all-pearlitic structure (Figs. 1 to 4) with widely varying total carbon and

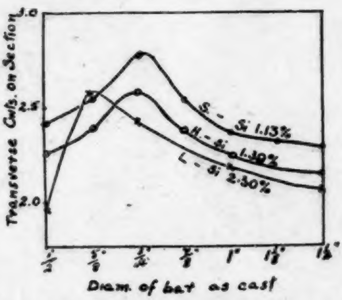


FIG. 1—CURVE SHOWING VARIATION IN TRANSVERSE STRENGTH IN RELATION TO DIAMETER OF BARS AS CAST

silicon, and even with different sized bars as shown by Beeny's paper (Foundry Trade Journal, April 24, 1924) which illustrates this point. He used three mixtures of the analyses given in Table 11.

Table 11

Total Carbon	Combined Carbon	Silicon	Manganese	Sulphur	Phosphorus
3.38	0.65	2.30	0.51	0.08	1.0
3.56	0.83	1.39	0.55	0.11	0.86
3.54	0.84	1.13	0.53	0.115	1.0

From each analysis he cast cars ½, ⅝, ¾, 1 and 1¼ inches in diameter in one box, all top run from the same runner, yet all

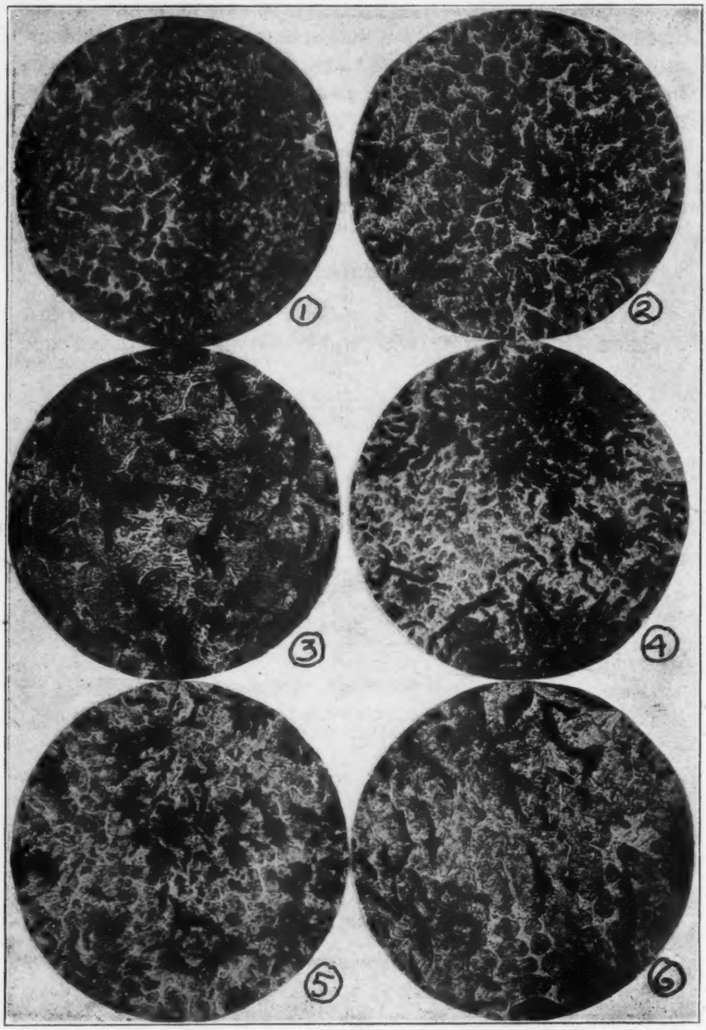


FIG. 2—(1), L 1 BAR (SI. 2.3, COMBINED CARBON 0.75) ETCHED, X 100;
(2), L 2 BAR (SI. 2.3, COMBINED CARBON 0.67) ETCHED, X 100;
(3), L 5 BAR (SI. 2.3, COMBINED CARBON 0.65) ETCHED, X 100;
(4), H 1 BAR (SI. 1.39, COMBINED CARBON 0.89) ETCHED, X 100;
(5), H 3 BAR (SI. 1.39, COMBINED CARBON 0.83) ETCHED, X 100;
(6), H 6 BAR (SI. 1.39, COMBINED CARBON 0.78) ETCHED, X 100.

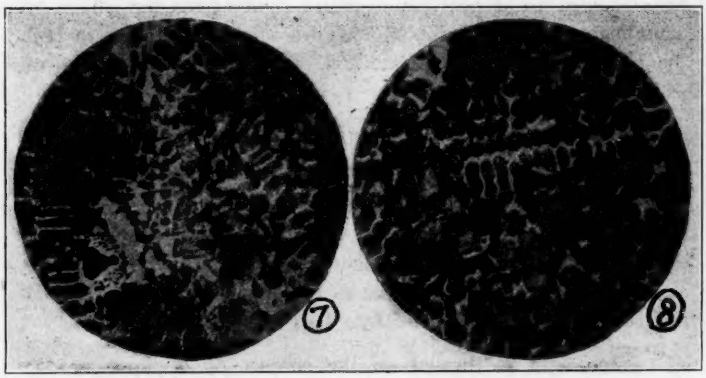


FIG. 3—(7), S 1 BAR (SI. 1.13, COMBINED CARBON 1.26) ETCHED, X 100;
(8), S 3 BAR (SI. 1.13, COMBINED CARBON 0.84) ETCHED, X 100.

FIG. 4—(9), S 7 BAR (SI. 1.13, COMBINED CARBON 0.79) ETCHED, X 100.

these bars, with the exception of the ½ inch from the last mixture, showed an all-pearlitic structure right across the bars. An examination of the microphotos shows a wide difference in both the pearlite and graphite condition. Maurer's results* confirm.

Maurer's Results Confirm Beeny's Results

Take Maurer's No. 66 with total carbon and Si = 4.46 per cent and No. 98 with total carbon and Si = 5.25 per cent, both are all-pearlitic; examine photos 42, 42A, 42B, on page 1811, all three again show an all-pearlitic structure, but again a coarsening of graphite and pearlite due to (a) mold being heated to 250 degrees Cent., and (b) to 450 degrees cent.

Some light is thrown on the subject by a paper by Dr. Klingestein. A chart is given showing the relation between physical properties to bar size and composition. From the diagram we gather that when using two sizes of bars cast from the same mixture, with 6.7 per cent total carbon and silicon, the 20 millimeter diagram bar gave 4.75 tons (10,640 lbs.) transverse more than the 30 millimeter bar; with total carbon and silicon 5.4 per cent. the 30 millimeter bar broke at the original figure of the small bar, but the latter was still the 4.75 tons (10,640 lbs.) stronger. But with total carbon and silicon at 4.8 per cent, both bars broke at approximately the same and highest result attained.

Bolton found the larger bar much more sensitive to small variations, hence it would be best to try out both the new B. E. S. A. bars, ½ inch and 2.2 inches diameters. This may add to the difficulty of the proposition with crucible melting, but with the known lack of homogeneity in cast iron, no other course is advisable.

The size of the molding box, number of bars per box, and that the sand be dried is of importance if comparable results are to be obtained. Take only three recent examples, Bolton, Maurer, and Hamasumi. In the first two you are given a heating and cooling curve of the sand in the box. Bolton also shows the cool-

*Von Ed. Maurer und P. Holtzhaussen, *Das Gusseisendiagramm von Maurer bei verschiedenen Abkuhlungsgeschwindigkeiten*, Stahl und Eisen, Oct., 1927, pp. 1805-1812.

ing curve of the bar on the same graph. Bolton's bars would be made in accordance with the American standard, viz:—two 1¼ inch diameter bars cast in a box approximately 10 inches square, top run and made in dry sand. The heating curve of the sand shows a quick rise to 112 degrees Cent., an arrest while water in combination is driven off and the sand attained its highest temperature of 338 degrees Cent., after 330 minutes. The temperature of the bars had by that time dropped to 676 degrees Cent.

Maurer cast three 1.2 inch bars in a core only 4⅞ inches in diameter. This mold attained its highest temperature of 340 degrees Cent. in 30 minutes and then steadily dropped. The difference in time is accounted for by the difference in method. All three of Maurer's bars were within ¾ inch from the outer edge of the mold and only 2⅛ centers radially, so the mold would heat up much quicker and also dissipate its heat quicker, due to the small size of the mold.

A comparison can also be drawn between the conclusion of Bolton and Hamasumi. The latter states that it took approximately 5½ minutes for his 1¼ bar to cool from the eutectic arrest point to 900 degrees Cent. Bolton took approximately 40 minutes for his bars to do the same. Here again the difference in procedure will account for the large variation. Hamasumi used a box 8 inches square, cast green sand and one bar in a box.

These large varitions in cooling rate must have some influence on the structure of the bar, and only shows the futility of comparisons unless some well-defined plan is generally agreed upon.

Summary of Part I

All the points dealt with in this paper could be further elaborated, but it is too long now. The author had three definite ideas in producing it:

First—to show our critics that the problem was not the simple one their criticism implied.

Second—that while the method of approach from a pure iron base was probably the best for steel, and even for cast iron in the

first stages, no serious advance has been made along these lines since 1913, and the time has arrived for tackling the full problem.

Third—a definite scheme is suggested. It may be crude, but would at least form a basis for discussion and improvement.

Part 2

The first part has dealt somewhat hurriedly with the theoretical side. But there is a much more serious issue that all practical founders must face if we are to regain lost ground, that is, the improvement and reliability of our material generally. Every time a casting goes out that is not right and without the knowledge of the buyer, the seller not only penalizes himself, but lets the whole trade down and adds to the lack of confidence in the material. We have been spending considerable time studying the technical reports of the "British Engine, Boiler & Electric Insurance Company," for the last twelve years. Too much praise cannot be given to these carefully prepared reports. Examples of various types of failures are given, together with the cause, with a view to avoiding a recurrence in the future. So far as the steel side is concerned, the writer displays a thorough knowledge of his subject. The various micros, tests, and sketches prove this. But with cast iron it is evident the author is not too conversant, and there appears on the surface an impression that cast iron is an unreliable material, and the sooner it is replaced the better. No analyses are given and only one set of test bars, and not a single micro. With some of his conclusions one can hardly agree. To quote one, No. 2458, April 3, 1917, "Killed, Injured. Cast iron heated oven. Composed of two hollow rectangular tables. The shelves were 2—11x1—8x3 inches overall externally. The top and bottom plates, which averaged $\frac{9}{16}$ inch thick, were strengthened by two rows of stays 1⅛ inches in diameter, cast in position, pitched about 6 inch centers. Steam at 120 pounds pressure was admitted by a ½ inch pipe into the upper shelf. This casting was tested to 240 pounds." Yet after eleven years with steam daily at 120 pounds it was stated, "That the *strains produced in the process of casting* had in the course of years resulted in the development of defects leading to the ultimate failure of the

stays." Testing to 240 pounds was more likely to cause incipient fracture, but a more likely cause would be the "breaking" action over 11 years expansion and contraction. The above is not written in any carping spirit. It is recognized to the full, that it is equally to the advantage of the insurance company and the ironfounder to reach the correct reason for failure, so as to avoid it in the future. How much fuller information would be appreciated goes without saying. Several of the failures in oil and gas engines would form an excellent basis for discussion at the various foundry branch meetings, were the reports given more in detail, such as analyses, micros, and tests. Such discussions would be helpful to all parties concerned.

While it is not possible to comment on the hundreds of reports given there is some consolation to be derived from the fact that, though there were numerous cases of molding faults, there were few failures due to metal alone in the higher grade machines, not near so many as steel, with wrong heat treatment and slag inclusions.

If we take turbo-generators and other electrical machinery, out of over 100 reports there are only three relating to cast iron. The first was due to wrong design, where a turbine built in 1912 had two stiffening ribs on the outside. These formed a source of weakness, owing to the slight "breaking" of the casing, and commenced to crack on the outer edge. When cut away, the cracking stopped. In 1926 a report is given of a 1500 K.V.A. impulse type turbo-generator, working at a pressure of 160 pounds pressure and a superheat of 300 degrees Cent. After five years cracks were noticed at the high pressure end, as shown in the Sketch, Fig. 5. The writer states, "cast iron is at no time the most suitable material for use with steam at high temperatures and less with a complicated casting." Yet the fact remains there are many turbines working at equal temperatures, with no sign of failure. Would it not have been better to get down to the root cause?

Steam engines and pumps:—In this section much of the trouble was due to faulty design, and neglect in working. Only

two definite charges were made against cast iron as supplied. (1) Cracked cylinder, after running 18 years "The trouble owed its origin to stresses set up when the part was cast." (2) A broken valve seat, part of which found its way into the cylinder and caused damage. "The fact that cast iron is an unsuitable metal for superheat steam is well known; the present case, however, illustrates a more serious danger than the mere failure of

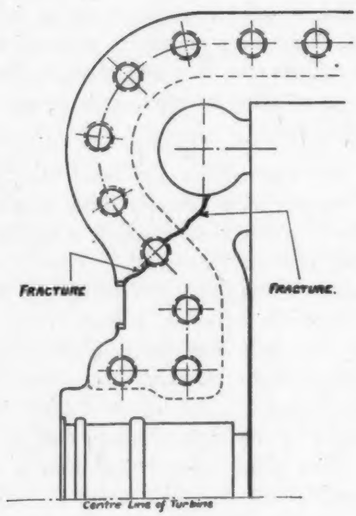
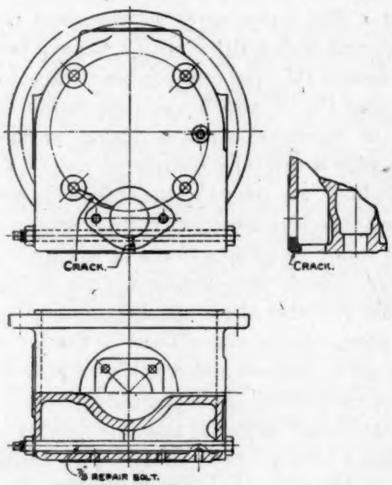


FIG. 5

a cast iron part, which may result from the injudicious use of that metal." Both of these conclusions are more than debatable, and, considering the thousands of similar engines that have been running many years, one would have liked some more reasoned explanation than a mere statement, especially in view of the fact that there are twice as many failures of steel parts, a number of which are due to defective material. Yet we find no wholesale condemnation as in cast iron.



PART SECTIONAL PLAN
SHOWING METHOD OF REPAIR

FIG. 6

Gas and Oil Engines:—The failures in this section are more serious from the founders' point of view. Fractured breech ends, cylinder jackets, and water jackets are far too frequent. While quite three-fourths are due to the use of unsuitable cooling water scaling up the water spaces, causing overheating, also to bad design, there are sufficient left to call for serious research both metallurgically and from the point of design. That in many cases failure is due to wrong analyses, goes without saying, else how is it so many stand up to the variation in expansion between the inner and outer casings? This is a case where test bars are almost useless and where your composition must be controlled to suit the design of your cylinder, especially where there are narrow jacket cores. An example was given in THE FOUNDRY last year, where a 25-ton jacket cylinder, owing to the heat retaining qualities of a thin jacket core, the combined carbon was reduced to 0.05 per cent with a Brinell of 89, while a bush cast from a similar metal showed 0.55 per cent combined carbon and a Brinell of 138. Discussing Fig. 6, which was temporarily mended after cracking owing to expansion stresses during working, the writer states, "Even with a carefully considered design, the metal is only able to withstand the stresses imposed on it, when the greatest care has been exercised during its casting, special attention being necessary in fixing its composition and in carrying out the mixing and pouring." With this dictum we are in perfect agreement and from the fact that there are thousands of gas and oil engines at work, goes to prove, that difficult as the job may be, a fair amount of success is attained and it is shown how vital it is that the true cause of the failures should be known. Complete analyses, micros, and tests should be taken and investigated as in steel. Take, for example, a broken crank shaft. Two photos are given, sulphur prints, micros showing excessive grain size, the result of incorrect heat treatment, and the full analysis. The tensile tests giving limit of proportionality, yield point, ultimate stress, elongation, reduction of area; stress shown diagram, ingot test. Compare with this the vague reference made to cast iron.

Lifts and Cranes:—No failures in this section due entirely to cast iron.

Explosions:—This section is by far the most serious from the founders' standpoint, because of the number of accidents that occurred due to material that had no right to have been sent out, causing loss of life and injury. There were twenty-four cases where pipes, valves, steam chests, etc., were out of section, causing a loss of fourteen killed and seventeen injured. "Rectangular chest 5/16 to ½ inch one side, 1 inch on the other," "C.1 tank should be ¾ inch, varied from 3/16 inch to ⅝ inch," "C.1 pipe ⅝ inch one side, 1 3/16 inch other," "Main stop valve 22/32 inch one side, 1 3/16 inch other," are a few of the worst examples. There is no excuse for failures of this type and, although the casting stood up to its work for a good number of years, the continual stresses set up by the variation in heating and cooling of the thick and thin side, must eventually lead to failure.

Another phase that comes out clearly from these reports is the thoughtlessness of works engineers with regard to both design and the pressures they put on to some castings. The severe screwing up of flanges with only a narrow thick packing between, the replacement of a few cast iron pipes with steel ones in a long range of pipes, with no arrangement for the extra expansion due to the double expansion of steel, taking a valve or tank from a low pressure main and inserting one with a much higher pressure, and many more matters of this sort. More than half the failures were due to water hammer and this was a fruitful source of failure in both steel and copper pipes.

In conclusion, we would ask the engineer to consider his side of these useful reports. He should place his orders for any castings under pressure with a reliable firm which has metallurgical control, insist on a rigid inspection, pay a fair price to cover this inspection, and also the extra control in the foundry. The founder we would ask that as we value our trade, we inspect our product carefully before leaving the works, and see that a suitable composition is used for all pressure work, even pipes. If our standard mixture is not suitable, make a special charge or two, and if this is against production, either obtain a price to cover the extra expense or refuse the order. We, none of us, like to do this, but if we are to regain confidence we must face

the difficulties. To the author of these very excellent reports we would again urge that he give us the fullest information. The research committees of the American Foundrymen's Association would render aid for any failures of American material, of which we noticed one or two, while we know the British Cast Iron Research Association would be more than willing to give assistance with British work.

Variables in Steel Foundry Practice[1]

By F. A. Melmoth,† Sheffield, England

Even in these days of acute competition, when the financial side of steel castings production must admittedly be perpetually to the fore in the minds of all producers, it is the ambition of every foundryman to produce the *perfect* casting. More than this, to have also an exact knowledge of what went to produce it, so that control and supervision, coupled with exact information, can repeat, again and again, the cycle of operations with unvarying success. After a good many years' experience, the writer has been forced to the conclusion that the dominating feature of steel castings is their inherent tendency to unexpected variation. Regular lines of procedure are laid down as the result of research and experience, but in spite of all precautions occasions arise when all expectations meet with disappointment and production does not proceed to schedule. It is, of course, just this capricious behavior which adds an intriguing piquancy to steel castings in-

[1] This paper is one of a series on foundry problems being exchanged between the Institute of British Foundrymen and the American Foundrymen's Association. The first, prepared by the late George K. Elliott, was presented at the 1921 meeting of the Institute of British Foundrymen. The second was presented at the Rochester, New York, meeting of the American Foundrymen's Association by F. J. Cook, past president of the Institute of British Foundrymen. Professor Enrique Touceda presented the third paper before the British Society. The fourth was written by Dr. Percy Longmuir; the fifth by Major R. A. Bull; the sixth by Wesley Lambert and G. Hall; the seventh by Dr. R. J. Anderson and M. E. Boyd; the eighth by J. E. Fletcher; the ninth by Dr. H. Ries; the tenth by Arnold J. Lenz; the eleventh by John Shaw; the twelfth by Dr. J. H. Andrew, the thirteenth by J. T. MacKenzie. This, the fourteenth paper of the series, is presented on behalf of the Institute of British Foundrymen. The fifteenth paper will be presented by John Howe Hall of the American Foundrymen's Association at the 1928 June meeting of the Institute of British Foundrymen at Leicester.

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vestigations, but to those of us who are responsible for costs of production, as well as quality, this represents very poor consolation. Our invariable question is, why do these things happen?

Light has been thrown on many of the dark places associated with steel production by the immense advance which has taken place in the application of scientific knowledge to practical needs. Research into the phenomena associated with steel has progressed at a very rapid rate, but, in the writer's opinion, its value is really limited by the degree to which it is adapted and applied to the practical problems of the industry. Research for its own sake is undoubtedly a high ideal, and has in the past added richly to our stores of knowledge, but to the producer of the world's goods, no matter in what form, only that which is practically applicable is of value.

Although he hopes for contradiction, based on facts, the writer definitely feels that in many ways the foundry industry as a whole has lagged behind the rest of the metallurgical trades, in the adaptation of scientific knowledge. He would ask, however, is this our own fault? Is it not equally true, at any rate, that the problems of the foundry have not been thought of sufficient interest or importance to merit the close investigation rendered to other branches?

There is no doubt whatever that the attitude of disregarding the foundry and its needs is vanishing. A perusal of modern foundry technical publications, papers submitted to various foundry associations, etc., will, the writer thinks, go far to prove this statement. The application of scientific knowledge to the production of gray iron, for instance, would appear to have been attended by very great success, and remarkable advances have been made.

Where the steel foundry is concerned, the attitude adopted appears decidedly to be improving, and no doubt similar beneficial results may be looked for.

The factors influencing the production of a steel casting to the greatest extent may be said to be:

(1). The human element.

(2). The influence of the various molding operations.

(3). The metallurgical behavior of the steel in the form of a sand casting.

(4). The heat treatment after casting.

The writer proposes to state his impressions of these influences, and to consider where, in his opinion, certain lines of investigation exist which offer profitable results.

(1). The Human Element

The influence of this varies according to the procedure adopted. In large production of repetition castings it seems obvious that possibilities occur of largely eliminating some of the more variable effects of personal manipulation. The standardization of method, introduction of machines, and so on, all tend to reduce these points at which individual ideas can affect the ultimate article. In the production of castings of a type suitable for repetition manufacture in large numbers, the writer most wholeheartedly would agree with constant attempts to eliminate, at any and every point possible, the effect of the human element. By this he means the introduction at any point, of the individual idea, not according to previously laid down plans. Such schemes centralize the actual higher grade knowledge required, to those responsible for the successful running of the shop, and the operators become semi-mechanical performers of predetermined operations. The skill and training demanded of the operator is of a different type, and more easily and quickly attainable.

Unfortunately, however, a large volume of business in steel castings is of an altogether different type. It calls for individual experience and skill in almost every one of its many operations, and the human factor becomes very often the deciding one between success and failure. Such castings will doubtless always be required, and therefore the question of the individual skill of the future operative is a matter of vital importance. It is significant that in almost all presidential addresses of the Institute of British Foundrymen, reference is made to the training of apprentices, and a knowledge of the skill demanded to handle some of the present day foundry propositions emphasizes the importance of the question.

Realizing then the inevitable influence of the personality of the operative, what are we to consider necessary to him in the way of knowledge which will enable this influence to be of a more beneficial nature? Skill in the use of his tools, and mechanical efficiency, he can gain by experience, and a carefully supervised apprenticeship to his trade, but will this enable him to keep step with the application of modern knowledge to his job? The writer does not think so, and finds it difficult to believe that satisfactory molds for steel, satisfactory handling of the produced castings, or satisfactory after treatment, can be assured if the man employed is not influenced by a knowledge of the material he is handling.

Obviously, the writer is not suggesting that it is necessary for an operative to be a skilled metallurgist, which would be an absurdity. An increased knowledge of the main known facts regarding steel, however, could not but help, and would guide the application of his craftsman's skill into correct channels. It would make understandable to him a vast amount of literature regarding his trade, which perhaps now is a closed book to him, and thus widen his opportunities of acquiring still more knowledge.

There is a definite possibility of an acute shortage of really skilled molders in this country, should there be any marked increase in the present demand for castings. It seems, therefore, all the more necessary that those available should have the widest and most complete knowledge possible. They might quite possibly come to be the nucleus of knowledge and experience round which future production schemes will be designed.

A further important fact incidental to the possession of a wider knowledge by the molder is that of the corresponding rise in the status of his trade certain to follow. The foundry industry does not ever appear to receive acknowledgment of the ability and skill demanded, although, in the writer's view, the real molder represents industrial skill of the highest order. It must be good both for the individual and the industry generally, that the intellectual standard should be raised, and this would doubtless be followed by a keener desire amongst boys to join the ranks of foundry workers, many of whom today avoid doing so because of a mistaken idea of its being work of a low grade, and dirty, compared with other skilled branches of trade.

The writer considers, therefore, that the curriculum for foundry apprentices should always include a course of elementary metallurgy. This can be of a very simple nature, sufficient to produce firstly a correct appreciation of the behavior of metal in sand molds, and precautions necessary to guard against the ill effects on the casting of the natural occurrences during its cooling period, and secondly, to give significance to the related and mutual effects of the metal on the material of the mold and vice versa.

Of the necessity for machine drawing, mechanics and elementary physics it is hardly necessary to speak. These are part of any syllabus designed for our apprentices. In Sheffield golden opportunities exist for the acquiring of all the necessary knowledge outlined. Apprentices are encouraged by most employers to take advantage of these facilities and merit is recognized. The university and education authorities have shown real interest and no excuse exists for any apprentice who fails to obtain for himself modern knowledge, and that necessary little extra which lifts him out of the common ruck.

It will be seen from the foregoing that the writer's opinion is that for this class of work we should admit the very great influence of the operative, and then by satisfactory training endeavor to guide that influence so that it may be less of a variable.

(2). The Influence of Molding Operations

By this the writer means the effect on the casting of the method of manufacture adopted, the molding, running and feeding of a casting.

No matter whether produced by repetition methods or otherwise, no success is possible in a steel casting unless the method adopted is the result of careful consideration. The writer feels that it is impossible to lay down rules applicable to each and all of the infinitely variable types of article demanded as castings. Each one must be considered as a separate entity, offering its own problem for solution. It is, however, probably a fair statement to say that more castings are spoiled by variations of a mechanical nature than by any other means.

All foundry men realize the importance of correctly planning

a job, deciding its position of casting, the placing and size of its runners and feeding heads, etc.

Patterns

Leaving aside the question of design, in which foundry opinion should be sought, but very often is not, the first point considered is the making of the pattern. On the way in which this is made depends a great deal of the ultimate success of the casting. Yet, how often is a founder supplied with a pattern made without consultation with him, and probably by a patternmaker who has had no experience of the particular metal now demanded, or the nature of the materials used to make the molds? In the writer's opinion the closest co-operation between pattern-maker and molding shop is called for on all jobs. The false economy of stinting the cost of patterns, the using of poor material, or by so-called economic design of pattern involving the foundry in a risky position or method of molding, are all realized by most foundry executives as being regular happenings. In repetition work, no such occurrence is really possible, as the number off and ultimate value of the order permits of free spending on pattern equipment, it being realized that security and lack of variation, not to mention rate of production, give a more than adequate return. But, as previously mentioned, vast quantities of steel castings have to be made which cannot be described as being of a repetition character. Yet it must be realized that very often an even higher standard is demanded from these jobbing castings than from repetition ones. Take, for instance, the case of steam pressure castings, turbine castings and similar castings. Accuracy of shape, perfect soundness, the exact placing of all cores, are matters of infinite importance, and yet design may alter considerably from order to order. When the significance of all these points is realized, one would imagine that patterns for such parts would be of the very best, and designed to mold and core up as the result of collaborated thought between pattern maker and molder. But is it not often the case that the molder is supplied with a pattern so designed that, owing to difficulties of withdrawal, or the insertion of cores, he is driven to mold in a position not entirely favorable to the production of a perfect job?

This then is surely the first of our points, that in all cases

the design and type of pattern supplied shall be the result of close co-operation between pattern shop and foundry, that the ultimate casting, both from quality and cost of production points of view, shall be the primary consideration. By this means, perhaps, one or more of our variables may be reduced in its number of occurrences and more regular castings result.

Molding Materials

The next process of a mechanical nature often involving possibilities of variation is the preparation of molding materials.

Here again we must necessarily sharply define the repetition production requirements from the needs of the shop handling a product of extremely varying nature, both as to size and type.

In the former, the writer considers it quite possible to so arrange matters that serious variations are a remote possibility. Assuming the articles made to fall within a reasonable range of size and weight, no great differences in sands required are likely to occur. Given, therefore, a consistent supply of the basis sand, and each consignment subjected to careful testing and examination before use, mechanical means and supervision at various points can be adapted to ensure regularity.

The case of the shop handling a large variety of work of widely varying types, is, however, very different. The material suitable for the small plain casting may be hopeless for the larger and more intricate one and for very heavy jobs involving massive sections of metal, an altogether new type of molding material may be called for.

This involves a multiplicity of molding sands, and in the writer's opinion, opens up one more serious possibility of variation. For a shop of this type increased supervision costs, as against repetition work, are quite normal.

The writer proposes to take the case of a British shop making a widely varying type of product and to show the classes of material in use in this particular case. It must be remembered that practice varies a good deal from shop to shop, and different materials may be in use elsewhere.

The work may be divided into three classes:

(1). Small green sand castings.

(2). Medium weight castings in dry sand.

(3). Heavy castings, usually made in composition.

Class 1: For these either a naturally bonded sand, such as Belgian, or equally satisfactory material found in this country, or what may be called a synthetic sand, may be used. The latter is merely a suitable grade of silica sand, milled with the necessary amount of refractory clay to produce sufficient bond for easy working, without seriously reducing its permeability to gases. In either case the possibilities of variation are similar, and are along two main lines. Extreme refractoriness is not a vital feature, as the small sections involved do not subject the mold to very high temperature for prolonged periods. The main lines of possible variation are therefore moisture content and porosity. Where sand consumption is regular the former is easily controllable by the instituting of regular moisture tests on the product of the sand mills.

Porosity, or permeability to gases, may be affected in many ways. The shape of the grains of sand is important, and obviously, the more nearly spherical the better. The writer believes this to be much more important than their actual size. Shapes which encourage the close interlocking of sand grains, already thinly covered by an envelope of bonding clay, will naturally tend to produce a dense compact mold, very liable to result in unsound castings. An excessive amount of the bonding material will also produce similar results, as the natural pores existing between the rounded grains of silica will, under the influence of packing together in molding, tend to fill up with impervious clay. Excessive moisture also contributes its quota towards reducing mold porosity, as it is realized that a wet sand tends to produce a close hard mold, through which the passage of gases is difficult.

To reduce our possibility of variations, due to sand in such castings, therefore, the points below are of importance.

(1). Grain size and shape determinations on the silica portion of the sand.

(2). Close control of moisture content.

(3). Careful milling of the sand to distribute the bonding material in the form of the thinnest possible envelopes round the sand grains.

(4). No heavy milling, liable to break up the original rounded grains of silica.

(5). Careful control of the amounts of bonding clay used, to avoid excess.

The supervision of the enumerated points can be made quite easily a matter of routine, and variables in these conditions are most likely to occur in the actual use of the sand itself, not due to its preparation. In this connection the human factor previously dealt with comes into operation, and may upset most carefully made arrangements. As an instance, it is not unknown for a molder, finding such a sand on the dry side, to add water on his own initiative. The previously carefully arranged quantitative preparation then stands for nothing, and a variable has been introduced, often with dire results.

The molds for small green sand castings are very likely made on molding machines of either squeezer or jolt ram type, and, as it is agreed that hardness of mold can affect the ultimate result in the casting, a further variable becomes possible. This can be largely overcome by proper arrangements, in the squeezer by the use of a sand frame, limiting the amount of sand, and in the jolt ram by limiting the jolts to a number proved to give a satisfactory mold. Owing to the almost impossibility of sufficient supervision to absolutely ensure this, however, there is little doubt but that a number of cases of variable results can be attributed to this point alone.

Castings of the Class 1 type are of thin section and often possess a number of bosses or local thick sections. The use of nails is often resorted to in order to assist soundness in these places. Owing either to their inaccessibility, or to question of cost involved in their removal, feeding heads are used as little as possible in such castings. Slight variations from regular fixed routine in the use of chilling devices, such as nails, are almost invariably followed by trouble with the castings. The use of dirty or rusty nails, or more often condensation trouble due to allowing a green sand mold, containing nails, to stand a period before casting, inevitably produces unsoundness in the parts affected.

Most green sand facings for steel castings are extremely open in nature, and do not call for a great amount of venting of the

mold itself, when the mold is small; but the question of dealing with gases evolved from cores during casting does appear of serious importance. The writer has experienced many serious troubles at times which were proved to be entirely due to lack of care in permitting free egress from the mold of gases evolved from cores. It appears rather futile to go to the trouble to produce a well vented core, and yet when inserting it into a mold to fail to make such arrangements as will allow these vents to function, with the consequence that blown castings result.

Summarizing our variables for Class (1) castings therefore, assuming the provision of correctly produced sand, we get the following:

(1). No correction of moisture content should be permitted at the discretion of the operative.

(2). The ramming conditions should be as consistent and fool-proof as possible.

(3). Any chills or nails should be perfectly clean.

(4). The molds should be cast as quickly as possible after closing.

(5). Vents from cores should be free, and carried outside the mold.

The influence of the nature of the backing sand is considerable on green sand castings. It has always appeared to the writer that it is not logical to insist on an open porous condition of the facing sand, while using a close, impermeable backing, liable to ram up like a brick. He feels sure that many cases of sponginess in castings might safely be attributed to this condition, and therefore, if variables are to be eliminated as far as possible would suggest a regular periodic examination of all heap sand, and its treatment if necessary to keep accumulated silt, etc., within safe limits.

Class 2. Medium size dry sand castings: The sands in use for this class of casting are similar in nature to those for Class (1), with the probable addition of small extra amounts of bonding material, and very likely a small content of some organic binder, to give a firm mold face after drying. With the exception of moisture content, all the points previously noted as needing careful attention if variations are to be avoided are just as important.

These molds are called upon to stand up to heavier sections of metal, which means that the mold face is at a high temperature for a more prolonged period. The question of refractoriness becomes of immediate importance. If the degree of refractoriness is low, fusion of the sand at the mold face is likely, with, at least, a resulting casting very expensive to fettle. In bad cases, also, fused portions of the sand may enter the metal as a liquid slag, and probably ultimately come to rest in a part subjected to machining. Probable rejection of the casting results.

The most likely variables entering into the manufacture of the molds for this class of casting are:

(1). Sand too close, thereby preventing the free passage of gases.

(2). The use of too much binder, either of the clay grade or organic type, thus giving a mold hard and impermeable.

(3). The closing of such a mold not completely dried with the resulting accumulation of steam in the mold cavity.

(4). The possibility of rusty or dirty chills or nails.

(5). Runners not properly covered with facing sand, so that old and weak sand is permitted to come into contact with the stream of metal.

(6). Drying at such a high temperature that the mold face is practically burnt. The binding agent is thereby rendered almost inert and the face of the mold is friable and weak, offering little resistance to the erosive action of the metal passing over it.

(7). The existence in the facing sand of fusible constituents lowering its refractoriness, which, under the influence of greater weight of metal and high temperature, results in partial fusion and the burning on of sand to the casting.

Class 3. Large heavy castings: In British practice most of these castings are made in some form of molding composition, it being generally accepted that normal molding sands with a silica base are not fully up to the job of withstanding the effect of very large masses of steel being poured over and on to them.

These compositions are very often made by the foundries concerned for their own use, and there is no doubt that many dif-

ferent mixtures are in use. The mixtures vary principally in relative quantities of the constituents, which, generally speaking, may be said to be the following:

Old crucible pots.
Used fire bricks.
Fireclay.
Sand.
Coke dust.

These are crushed in the required amounts, and the resulting mixture moistened to the necessary extent to produce a satisfactory bond for molding purposes.

All the points requiring consideration in ordinary molding sands are of at least equal importance in these compositions. Grain size and shape, in order to ensure porosity, are of outstanding importance, but the author would give first place to refractoriness. For the lighter classes of steel castings, where the mold face is not subjected for long periods to high temperature and at the same time to heavy superimposed masses of liquid steel, refractoriness is not so vitally important. For the heavy types of casting, however, any shortcoming in this respect results in extreme difficulty in the fettling shop. The variations likely to be introduced via the mold, therefore, are the same for heavy castings as the lighter ones, with the added tendency to increased mold fusion with consequent adherence to the casting. The materials from which such compositions are produced must be most carefully chosen, and hand picked for the removal of unsuitable constituents such as slag, etc., which would tend to lower the refractoriness of the resulting mixture.

In order to produce an improved skin on the casting, these molds are almost invariably painted before drying. The constitution of the paint used is of importance, most particularly from the standpoint of refractoriness. Obviously, it is in complete contact with the liquid steel forming the casting, and a low fusion paint will result in its partial or complete liquefaction, the slagging result being carried very often to dangerous places on the casting itself. The paint used, therefore, should be of a highly siliceous and refractory nature, and the writer has experienced serious

variations in the character of the produced castings definitely associated with variations in the paint used.

It is not uncommon for these large molds, made in composition, to be tarred after their removal from the drying stove and while still at a high enough temperature to burn out all volatile constituents of the tar.

In these cases, it is necessary to remember that an excess of tar, or tarring at too low a temperature, is very liable to induce a state of affairs which will almost inevitably produce porous castings.

The most likely factors, attributable to the mold materials, likely to cause variation in the production of molds for this class of work, might be summarized as follows:

(1). Composition too close, the grain size being too fine to permit of free passage of mold gases.

(2). The use of too much clay bond, resulting in the same disadvantage as No. 1.

(3). The accidental introduction into the mixture of some less refractory constituent causing fusion of the composition under the influence of high temperature and liquid steel pressure.

(4). The use of a paint for the molds of a not sufficiently refractory nature.

(5). Tarring of molds, either excessively, or at too low a temperature, inducing increased gas formation during casting.

There are, of course, numbers of possible variables common to all these classes of casting, such as accuracy of molding tackle, precautions to ensure accurate coring up, adequate cramping or weighting of boxes, control of speeds and temperature of casting and so on, and attention to all these points is desirable if consistent production is to result.

3. *Metallurgical Variations*

The writer quite recently heard steel castings described by a prominent metallurgist, as, "Badly designed ingots," and believes this to be a definition which, while being somewhat original, is also largely true.

For very many years research of the highest order has en-

deavored to produce orthodox steel ingots which are perfect in all respects, and free even from microscopic imperfections. The writer believes it to be a correct statement that the production of the perfect ingot, consistently and commercially, is still an unaccomplished feat. When it is remembered that for the greater part of the steel trades production, ingot design can be varied purely to produce the most ideal ingot, without effect on the ultimate article; but that in the case of a casting its design is fixed by the requirement, and the founder must overcome, so far as he can, any difficulties thus involved, it should be easily appreciated that troubles are very likely.

It is this fact which should always influence the designer when considering any new proposition. A realization of the fact that even a symmetrical ingot, well designed, is not free from metallurgical imperfection, should to such a person tend to check undue optimism regarding the production of some of the weird and wonderfully disposed, indeterminate sectioned, masses of metal demanded at times of the modern steel founder.

The laws of liquid and solid contraction are immutable, and the business of the steel founder is to realize them, and take such steps as will, to the greatest possible extent, neutralize their detrimental effect on the casting.

The intelligent performance of this naturally calls for study of the behavior of steel when cooling from the fluid condition in a sand mold, and coincidently a knowledge of steel itself. This point was emphasized as a necessity earlier in the present paper.

As distinct from variables induced by the action of sand molds on liquid steel, a host of factors inherently belonging to the steel itself can produce variations in results, some of which are none too well understood, and often cause mystification, when attempts to allocate causes are made.

The simplest cases are those associated with variations in what might be called orthodox composition. In the case of a plain carbon steel for castings, the effect of variations above or below the normal may be taken as follows:

Combined Carbon. (A). If too high. Castings short of ductility, probably hard to machine.

(B). Too low. Material very soft, but liable to fail to meet specified strength in tensile test. Wearing properties adversely affected.

General behavior of steel in a mold is not seriously affected by comparatively small variations in carbon content. When considered over a wide range of variation, however, the steels possess very different characteristics. A high carbon content is coincident with a lower melting point, which necessarily means that at a given temperature such steel is more fluid and easily cast into thin sections than is the case when carbon content is very low.

It is the writer's opinion also that the lower the carbon content the more difficult it becomes to produce absolute freedom from unsoundness of the porosity type. Very low carbon steels appear to have a great capacity for mold gas absorption, intensified, no doubt, by the fact that their high temperature of solidification necessitates an unusually high temperature of casting. Low carbon steels are not remarkable for their fluidity and the writer suggests that a low degree of fluidity predisposes to unsoundness in steel for casting in sand molds.

In straight carbon steels the carbon content may be said to be the main controlling factor of the ultimate strength of the material. The series of tests given in Table 1 will demonstrate this fairly well, the coincident increase of tensile strength and carbon content showing what might be expected from annealed steel castings of these carbon contents, other elements remaining constant.

All the samples were annealed, and slowly cooled in the furnace in order to ensure equality of temperature and cooling speeds in all cases.

The test bars were in all cases attached to commercial types of casting, and the treatment being normal may be taken as indicative of the everyday product given similar treatment conditions.

Table 1

Analysis			Max. Stress Pounds per Square Inch	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area	Degrees Cold Bend 1"x¾"
Carbon	Silicon	Manganese				
0.15	0.20	0.81	62,272	34.0	52.5	180
0.18	0.30	0.83	73,024	34.0	49.0	180
0.26	0.37	0.84	74,816	33.0	54.2	180
0.35	0.38	0.79	85,468	24.0	44.5	180
0.46	0.28	0.73	93,184	22.0	33.6	Not taken

Variations of carbon content outside ordinary manufacturing limits of accuracy are entirely a matter of steel making practice, and are today of rare occurrence.

Such variations become matters of importance, even if of comparatively small degree, when they occur in such dead soft steels as are used in the manufacture of various electrical requirements. In these cases a certain demanded degree of magnetic permeability is common, and carbon content has a decided action on this property, increasing carbon progressively lowering the magnetic permeability.

The permeability curves M and M1 (Figs. 1 and 2) demonstrate this point clearly. It will be seen that the value of magnetic flux B in sample represented by Curve M is much higher than the one shown by M1 at a given value of magnetic field H. The analyses of the samples used are given as an explanatory reference:

	Carbon	Silicon	Manganese
M	.12	.20	.40
M1	.21	.20	.65

The treatment is identical in both cases, being straight annealing at 850 to 900 degrees Cent. followed by slow cooling.

Silicon: This element in ordinary commercial steel castings is almost entirely present in order to assist soundness by the removal of oxide. In normal quantities it may be said to have very little effect on the physical properties of the materials. The writer's experience would suggest that in excessive quantities there are, however, possibilities of variations being produced in the resulting casting. High silicon in mild steel castings tends to the production of a coarse ferritic structure with consequent lower strength or resistance to shock impact. Several cases of abnormally low yield ratio have also been noted, explainable only by the presence of unusually high silicon content.

The main trouble experienced, however, is not one of effect on ultimate physical properties, but one associated with the behavior of the molten steel in the mold. The writer has, in previous papers, emphasized the gas absorption capabilities of

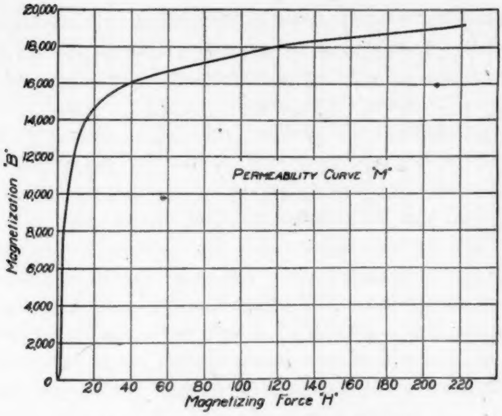

FIG. 1—PERMEABILITY CURVE "M"

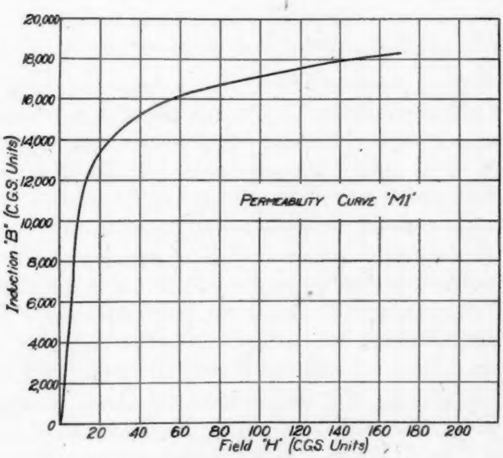

FIG. 2—PERMEABILITY CURVE "M1"

mild steels, particularly when produced by the electric process, and subjected to strongly reducing slag action. When thus produced, such steels would appear to possess in an aggravated form the capacity to absorb temporarily, in their passage through the mold, large quantities of evolved mold gases, releasing them with blowhole production, during solidification. This action would be expected to be governed in degree by the casting temperature of the steel, and this is doubtless to some extent true. In addition, however, the writer suggests that high silicon content, with high temperature, tends to produce the most favorable condition for temporary absorption. The effect is most marked in the production of green sand castings of a light type, and the occurrence in practice of repeated unsoundness in such steels would appear to emphasize that silicon variations should be avoided as far as possible.

It is hardly necessary to enlarge on the effect of abnormally low silicon, in the absence of other powerful deoxidizing elements. Free oxide of iron existing in the steel at the time of casting, reacts with the carbon present, and produces "wildness," in which condition no possibility of a sound casting exists.

The writer, together with G. Batty, has endeavored to associate silicon content with fluidity of the steel as cast. Over a very large number of electric furnace casts it is strongly suggested that abnormally high silicon produces a material much more difficult to cast from small shanks, than when silicon content is normal. The principal point observed is the tendency to skin over on the surface of the metal immediately it is exposed to the air. It appears incorrect to state dogmatically that this is due to the direct action of the presence of the silicon, as it may equally be due to the furnace condition which tended towards the production of high silicon content. These charges are frequently very dead, and result from strongly reducing conditions. Even when very hot they do not exhibit the usual degree of fluidity, and have been designated "dazed" heats. The condition is remediable by a return to oxidizing conditions in the furnace, afterwards finishing as usual.

A further peculiarity which might legitimately be included as a silicon variable is the case where silicon content has been affected

by a highly siliceous slag being allowed to form on a basic electric charge. This obviously is the result of overheated brickwork, but very peculiar effects have been noted, which are worth recording. At very high temperature, which certainly is the prime cause of this occurrence, silicon can be reduced from the silicates in the slag and enter the metal. The writer is of the opinion that it cannot be definitely stated that silicon thus introduced exists in precisely the same state and has the same action as silicon introduced in the orthodox manner as ferro-silicon or silico-manganese. Charges have been noted, fortunately rarely, which have been thus affected, and which have been impossible to quiet by any deoxidizing medium. Their silicon content has been high, occasionally so high as 0.7 to 0.8 per cent, but as soon as cast into the mold they have immediately risen badly. Further treatment in the furnace has no curative effect, but solidification, and re-melting appears to remove the trouble. The furnace samples of such charges do not always indicate their character; being perfectly sound, it is suggested therefore that the condition is an exaggerated form of the effect of high silicon and temperature previously referred to, with the possibility of some abnormal association of the silicon content.

Manganese: This being one of the most important elements found in commercial steels, it follows that variations of a serious order are to be avoided. It functions primarily as a deoxidizer of a very efficient type, assisting soundness very greatly, particularly in green sand castings. It is suggested that this is due to the tendency to enable iron to retain dissolved gases in permanent solution. In this respect its action varies from that of silicon, which, although apparently increasing such solution capability, confines its effect largely to the liquid state; evolution of the dissolved gases taking place in solidification.

Manganese forms a double carbide with iron and has pronounced physical effects in the ultimate casting, apart from its value to the founder as a help in producing sound castings. Tensile strength and yield point are materially increased without any serious loss of ductility, by the presence of a fair percentage. Where castings are required for specially high duty, and quenching and tempering operations are resorted to, a comparatively high

percentage of manganese appears to increase considerably the intensity of the quenching action, and remarkable physical properties can be thus attained.

A still further beneficial action of manganese is its effect on the condition of sulphur content. Where the latter is liable to run high, an ample percentage of manganese, by the formation of manganese sulphide, prevents the occurrence of iron sulphide which exists in such a form as to be very detrimental to the physical properties of the steel.

The effect of manganese is of course seen to the full in the high manganese-iron alloy known as manganese steel, discovered and developed by Sir Robert Hadfield. In this steel approximately 12 per cent of manganese exists, and given accurate treatment the product possesses strength, resistance to wear, and ductility of an almost amazing order. It is comparatively easy to cast and for parts subjected to the most gruelling of hard wear conditions is probably supreme in its class.

Bearing in mind the many effects of manganese content, it will be obvious that serious variations in the amount of its occurrence can considerably affect the properties of the casting. It is fortunately quite a simple matter in all methods of modern steel manufacture to maintain regularity in this element and fluctuations of a serious order are therefore a variable that should not exist in a well managed shop. In ordinary steel castings 0.8 to 1.2 per cent is commonly accepted as normal; variations inside this range being largely a matter of individual opinion.

Sulphur: This element is probably looked upon with more suspicion than any other in a steel casting, and to some extent this attitude is well founded. It often appears to the writer, however, that exaggeration of its effect is a possible feature. Cracks in steel castings are often attributed to this element, which are much more likely to be due to inefficient precautions in the making of the mold.

It was not uncommon, before the advance of metallurgical knowledge made it impossible, for the founder to turn a suspicious eye on his metal as a possible cause of any unexpected variation, or trouble with a casting. The admittedly detrimental

effect of really high sulphur content would make it easy to exaggerate the effect of quite small and unimportant variations. Such a state of affairs was doubtless very convenient to the molder, but it is generally admitted that in the presence of a reasonably high manganese content, sulphur content of an amount usually present in steel castings is unlikely to be the cause of serious trouble, either from the point of view of casting cracks, or effect on ultimate physical properties.

The very low maximum limits placed on this element by many specifications will undoubtedly have assisted towards a magnified conception of its ill effects.

It is not intended by this statement to infer that sulphur is not detrimental if present in abnormal percentage. Steel is definitely red short if it contains a high percentage of sulphur, and therefore prone to crack when subjected to contraction resistance while cooling from the molten condition.

Serious variations on the high side should be avoided, and present steelmaking methods are easily able to guarantee a sulphur content of an order impossible to associate with trouble in the casting. Where acid processes are the rule, this entails care in the choosing of materials, and an organized analytical checking system as no refining action is possible. Where basic lined furnaces are used, sulphur can very easily be removed to almost traces and no danger should exist of serious variation.

It is generally accepted that 0.06 per cent can be taken as a perfectly safe upper limit.

Phosphorus: This element is often associated with sulphur in the degree of suspicion with which it is regarded. In excessive amounts its action can be taken as being a tendency to reduce resistance to shock. Its effect on general physical properties does not appear important in normal amounts. In steel it exists in such comparatively small amounts that it also exerts no influence on the behavior of the metal in the molds. The writer has heard the opinion expressed on many occasions that a variation even from 0.03 to 0.06 per cent accounts for a marked increase in the degree of fluidity of the metal. He has, however, no evidence to confirm this as a result of his observations, and is more of the

opinion that the increased fluidity was a direct outcome of the melting conditions which coincidently produced a higher phosphorus. As an instance, one might quote the cases of electric steel made by single and double slag processes. The fluidity of the former is almost invariably higher, and its phosphorus content also will be higher. On the other hand, by so treating the single slag as to produce strongly reducing conditions the advantage in fluidity can certainly be removed, although the phosphorus content will remain the same.

Working with an upper limit of 0.06 to 0.07 per cent the writer has detected no detrimental effect.

To prevent variation in this element the precautions naturally vary according to the steelmaking method employed, and are the same as those noted for sulphur.

4. *Influence of Process*

A factor which might be considered under the heading of steelmaking variables is that of the influence of steelmaking process.

Theoretically it might be assumed that steels of equal general composition should behave similarly, and give comparable results in the product, irrespective of the process by which the steels are made. Practical experience of material produced by various processes suggests, however, that this is not the case. It appears to the writer therefore that this might be taken as a variable to be considered where steel processes are liable to undergo a change in type.

For heavy work, the Siemens open hearth furnace practically monopolizes the demand, being the only type of furnace at present capable of producing commercially large enough single charges. It is therefore more in the direction of the medium and lighter classes of casting that variations of steelmaking process are likely to occur.

The general opinion of many steel foundrymen would suggest that the main point of variation is in the actual behavior of the steels during casting, that is, in their comparative degree of fluidity, which mainly controls the ease with which a steel casting

can be run. In the writer's opinion, which is based on observation over large quantities of steel of each type, the following would represent the order of the various steelmaking processes based on their comparative ability to produce steel with a degree of fluidity high in proportion to its temperature. The crucible is omitted owing to the comparative infrequency of its use at the present time.

(1). Converter.
(2). Electric furnace (single slag).
(3). Siemens open hearth.
(4). Electric furnace (double slag).

In placing electrically produced double slagged steel at the bottom of the list, the writer will probably meet with a good deal of opposition. He would emphasize, however, that the steel he has in mind, classified as very low in fluidity, is that produced when the bath is subjected to the action of strongly reducing slags, for considerable periods. When this is the practice the writer has always found that to a greater or less extent, depending on degree and time of the action, fluidity is markedly lessened, and it consequently becomes more difficult to run light sections.

Various suggested explanations have been forthcoming from time to time, to account for this variation, and also that frequently claimed between electric and converter produced steels of the same analysis. The present writer's opinion and tentative suggestions were set forth in a paper given to the Manchester Branch of the Institute of British Foundrymen some time ago, and in order not to unduly prolong the present paper he would refer those interested to this publication. It will perhaps suffice to say that the writer has seen no reason to modify seriously his opinion since the date of the paper referred to.

A good deal can be said with regard to the influence of steelmaking process on the regularity of the composition of the castings produced. The electric furnace with a basic hearth stands preeminent in this respect, its freedom from slag losses making it a fairly simple matter to maintain regularity of analysis well within practical limits.

When producing certain special classes of work, notably those calling for alloy steels, variables from the composition standpoint cannot be countenanced, owing to the significance of the alloying element on the ultimate service performance of the casting. It is here that the real benefit of electric melting can be truly appreciated. It is perhaps fair to say that there is no special element used in such steels which is not under more perfect control in the electric furnace than in any other type. With correct slag conditions, which are attained without difficulty, quantities in the casting become merely a question of calculation, as losses are practically negligible.

The production of straight carbon steels accurate to analysis is almost as straightforward a matter in the Siemens open hearth as in the electric furnace, and in this class the latter furnace cannot demonstrate any serious advantages.

In the writer's experience the converter, while producing a steel very suitable for light castings, cannot be said to attain the regularity of product obtainable from the other two processes mentioned. This is probably due to the fact that the critical period of the blow, which controls very largely both character and composition of the product, is both very short and also entirely in the control of the human deciding factor. This calls for both high skill and long experience if regularity is to be assured.

Deoxidizers: Associated with steel production, and certainly having an influence as a variable is the use of various deoxidizers other than the silicon and manganese content normally present. The use, or more important, the abuse, of such materials, can induce effects in the casting of quite a serious order. At the risk of being accused of platitude, the writer would emphasize that these useful materials should never be permitted to become apparent remedies for bad steelmaking practice. They are in no case capable of turning badly made steel into good steel, and their use in such circumstances often produces a condition in the casting which is positively dangerous.

Taking first the case of aluminum, the writer considers it quite possible to produce perfectly sound castings without its use. On the other hand, he has always used it in moderate amounts as

a safeguard, principally in green sand castings. He is satisfied that if added in small amounts to previously well made steel, aluminum tends to confer on the steel a certain degree of capability to resist the unbalancing effects of mold gases and water vapor. A charge of steel of a rising nature cannot be safely corrected with aluminum. In such a case large amounts are called for, and the oxidation of the aluminum produces a dirty steel, and ultimately castings much reduced in strength. Such charges should invariably be returned to the furnace and corrected in a proper manner.

Apropos to the use of aluminum, the writer has often seen it used by placing pieces in the mold, it being intended that the steel should take it up during its passage through the mold. If this is done it is necessary to be sure that the pieces are very small and thin. An experience some years ago has made the author very chary of introducing aluminum in this way. Certain castings showed extremely hard spots on the bottom face as cast, and it was impossible to machine them satisfactorily. The steel being satisfactory in composition and structure, and the position of the hard spots making it impossible to contemplate segregation, the matter called for investigation. It was found that porosity had been experienced on this bottom face, and with a view to preventing this quite local defect, small pieces of aluminum were placed in the mold. The hard spots were cut out and examined and it was found that they contained anything from 10 to 20 per cent of aluminum. It seems feasible that the chilling effect of the green sand mold had been sufficient to solidify the steel in contact with the mold before complete diffusion of the pieces of aluminum could take place, with, of course, the production of a hard alloy of iron and aluminum.

Ferro-titanium of both carbon-containing and carbon-free types is often used in steel for castings. The writer has only used this material in castings made from electric furnace steel, and if added to the furnace and thoroughly absorbed by the bath before tapping some small benefit in the strength of the product was noticeable. Its cost compared to the benefits achieved did not, however, permit of its regular use, as it was considered that equally good results could be obtained at much less cost. In any

case, it was considered essential to add it in the furnace, and not in the ladle.

Calcium silicide is another material very commonly used as a final deoxidizer. Its use in moderate quantities is undoubtedly useful, but the remarks regarding the use of aluminum apply also in this case. All the materials, while representing useful special additions to steel, are in no way capable of nullifying the effects of poor steelmaking practice, and the degree of their use might even be taken as a measure of the perfection of the steelmaking methods employed.

Heat Treatment: When it is appreciated that no work can be placed on a steel casting with a view to breaking down the coarse cast structure commonly present before heat treatment, it is realizable that this operation is capable of producing many serious variations if inefficiently carried out. Almost all steel castings are submitted to treatment nowadays, and their ultimate capabilities can only be really produced by a correct procedure in this operation.

The bulk of general engineering castings are made from mild steel, which in its cast form, slowly cooled in a sand mold, exhibits a coarse, strongly crystalline structure. As might be expected, such a condition is coincident with physical properties of a comparatively low order, and very small resistance to shock.

The following is a typical test result of such a mild steel in its sand cast form:

Max. Stress Pounds per Square Inch	Yield Point Pounds per Square Inch	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area	Cold Bend	Izod Impact Foot Pounds
66,752	33,600	14	18.58	87° broken	15

Micro photographs 1, 2, 3 and 4 of Figs. 3, 4, 5 and 6 will no doubt fully demonstrate the reason for the low elongation and impact figures. Micros 1 and 2 being of the unannealed structure a 50 and 200 diameters respectively, and micros 3 and 4 being representative of the annealed structure at 50 and 200 diameters.

Such material does not represent a satisfactory product for the bulk of engineering requirements. The figures below are from tests from the same charge taken after a perfectly straight-

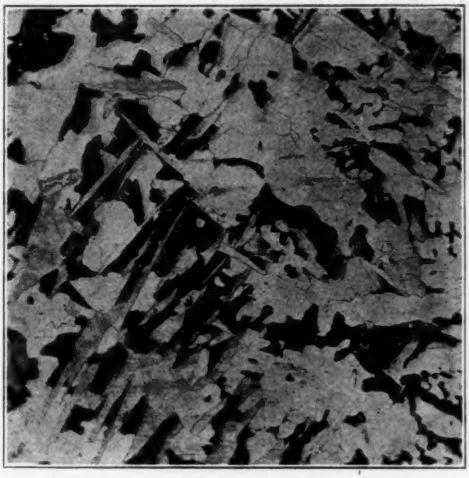

FIG. 3—MICRO (1) MILD STEEL CASTING, AS CAST, X 50

FIG. 4—MICRO (2) SAME AS (1), X 200

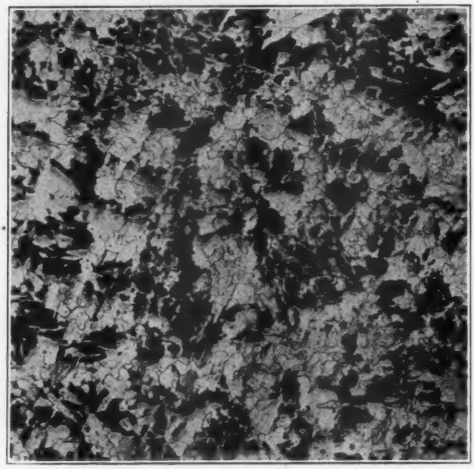

FIG. 5—MICRO (3) MILD STEEL CASTING, HEATED TO 875 DEGREES CENT. FOR TWO HOURS, COOLED IN FURNACE, X 50

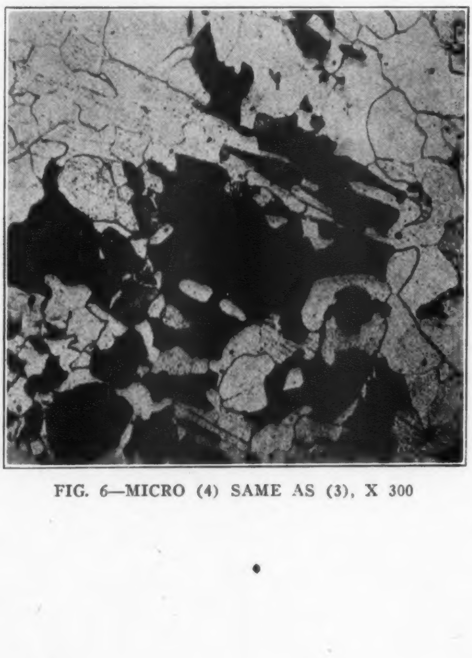

FIG. 6—MICRO (4) SAME AS (3), X 300

forward annealing process at 875 degrees Cent. followed by cooling in the furnace.

Max. Stress Pounds per Square Inch	Yield Point Pounds per Square Inch	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area	Cold Bend 1 Inch Diameter	Izod Impact Foot Pounds
69,888	37,184	26.5	31.58	180° unbroken	36

It will be seen at once that a very great improvement has been brought about. Examining the figures in relation to the structure shown in micro photographs will show that the removal of the coarse angular crystalline structure has resulted in a large increase in the ductility of the steel, and in its resistance to shock.

A short study of this very simple case will doubtless be sufficient to emphasize the necessity for lack of variation in such an important operation. The real physical capabilities of a steel either of the straight carbon or alloy type are never exhibited in its cast form, but are only potentially present, able to be evolved by correct heat treatment.

Such treatment will, of course, vary according to the nature of the steel composing the casting, and to some extent also according to the service demand made upon it.

The great majority of specifications for mild steel castings can be easily met by a straight annealing, cooling either in the furnace, or in air, the latter depending principally on the type of casting being handled. Castings with heavy sections would obviously be very liable to fracture if quickly cooled and these are almost invariably cooled in the furnace. The lighter types, however, can safely be cooled in air, resulting in a somewhat higher tensile strength and yield point, while ductility remains practically unaffected. If complicated in type, air cooling can be followed by a second heating to a lower temperature, say 600 degrees Cent., with advantage.

While such a treatment will enable any initially good material to conform comfortably to standard specifications, the limits of the capabilities of the steel are not by any means reached. In certain special cases, and where size and design of casting permit, a marked further improvement is obtained by quenching the casting in water or oil from 850 to 900 degrees Cent., afterwards

repeating to a lower temperature, say 450 to 600 degrees Cent., depending on the properties desired.

These remarks apply with considerably greater force in the case of alloy steel castings. The real benefits of the presence of the alloys can only be attained by a correctly designed method of heat treatment. Taking the case of a nickel-chrome steel as an example, the best result from this material, quenched in oil from 850 degrees Cent. and afterwards reheated to 550 to 600 degrees Cent., gave the following:

Maximum Stress Pounds per Square Inches	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area	Cold Bend ¾"x⅜"
119,168	24	52.4	180° unbroken

A test of this high standard is, of course, out of the question unless the casting is subjected to a carefully designed and controlled treatment, and the figures are given as a matter of interest, and to show, that even in casting form, subjected to no mechanical work of a structure refining nature, such steels are capable of being put into a remarkably satisfactory condition by heat treatment alone.

Manganese steel, as is well known, depends entirely upon the efficiency of its heat treatment to exhibit its unique properties, and no matter how good the initial material, no success is possible with this product until its treatment is thoroughly understood.

These somewhat sketchy remarks on heat treatment are given with the idea of adding emphasis to the importance of correct treatment, so that the real necessity of suppressing variables will be appreciated. The writer is aware that, even today, founders not able to avail themselves of expert metallurgical knowledge are liable not to attach full importance to the operation, with the result that their product can never exhibit its best capabilities.

The main function is obviously temperature, and as detrimental results follow either too low or too high temperature of treatment, these are the first variables to be avoided. This can only be done regularly and satisfactorily by correct temperature control by means of modern instruments. Accurate pyrometers, correctly placed to indicate the real temperature of the material itself, and not the furnace atmosphere only, are an absolute essential.

The length of time required is controlled by the thickness of section involved, and variations in result are not uncommon from a lack of appreciation of this fact.

Faults which can be directly attributable to incorrect manipulation during treatment can be tabulated as follows:

(1). *Too low a temperature:* The coarse "as cast" structure is not completely removed, and the physical properties are very little affected as compared with those of the untreated product. The solution of the cast structure, and its recrystallization in a much finer form, can only be attained by temperatures above the upper recalescence point of the material.

(2). *Too high a temperature:* The cast structure is removed, but as the coarseness of the final structure is largely dependent on the temperature from which the casting last cooled, its structure will be now much coarser than necessary, and its physical properties correspondingly lowered. In addition, the castings will be badly scaled, and probably distorted.

(3). *Too short a period at temperature:* As stated previously, time required is controlled principally by the thickness of section involved, and the result of too short a time for a given section will be that the solution of the cast structure will not have proceeded to completion. The remaining strongly crystalline and angular structure will cause the casting to possess physical results lower than the true capabilities of the material.

Apart altogether from the changes in microstructure with coincident improvement of physical properties in the casting, there are two further directions in which possible variations of result may take place.

The first is that of the action of heat treatment in the removal of stress existing in the casting as received from the mold. These stresses can be of a two-fold character, the first being those induced by variations of section thickness and consequently locally varying cooling speed in the mold, and the second, the stresses resulting from hindrance to the normal contraction when cooling from the molten condition. In effect these may be taken as identical in their action, which, briefly stated, is that they cause the

casting to contain, locked up in its crystalline structure, stresses of varying degree, liable as a result of shock or sharp changes of temperature to fracture the casting. The coarsely crystalline structure, possessing very definite lines of cleavage, is susceptible to fracture from this cause, and the refinement by treatment renders it much less likely that stresses will release themselves by fracture. In addition, the slow and even cooling associated with the annealing of heavy or complicated castings removes these stresses to a very large extent.

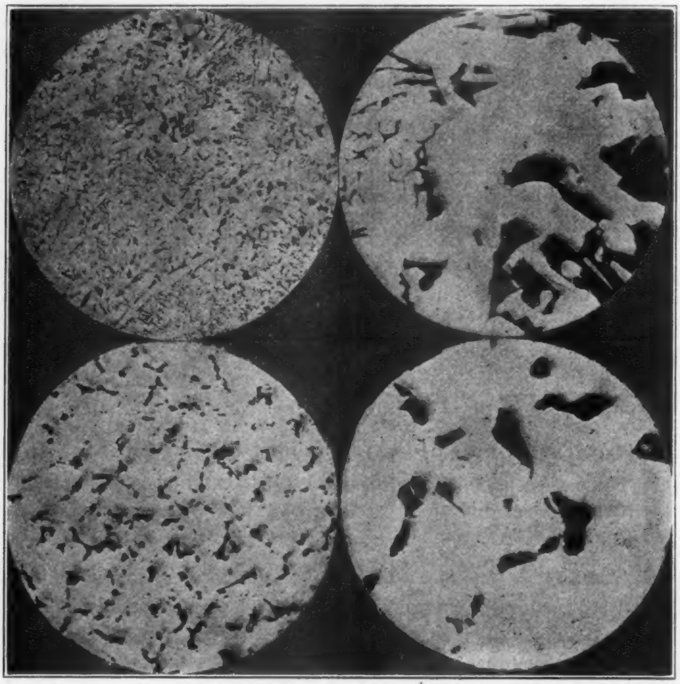

FIG. 7—UPPER LEFT, C 0.14, Si 0.30, Mn 0.83, AS CAST, X 30; UPPER RIGHT, SAME AS UPPER LEFT, BUT X 200; LOWER LEFT, SAME AS UPPER LEFT, BUT ANNEALED AND SLOWLY COOLED, X 30; LOWER RIGHT, SAME AS LOWER LEFT, BUT X 200.

Assuming a steel casting to be of the heavy and complicated type, sure to be in a state of considerable stress as received from the mold, anything which can even momentarily add to these stresses is capable of causing fracture.

A variable, not always easy to control in such cases, is the increasing to the danger point of the stresses by uneven or too quick rise of temperature in the heating up process. In many types of steel, this can very easily result in fracture. With such castings it is always safer to put them into the furnace before becoming

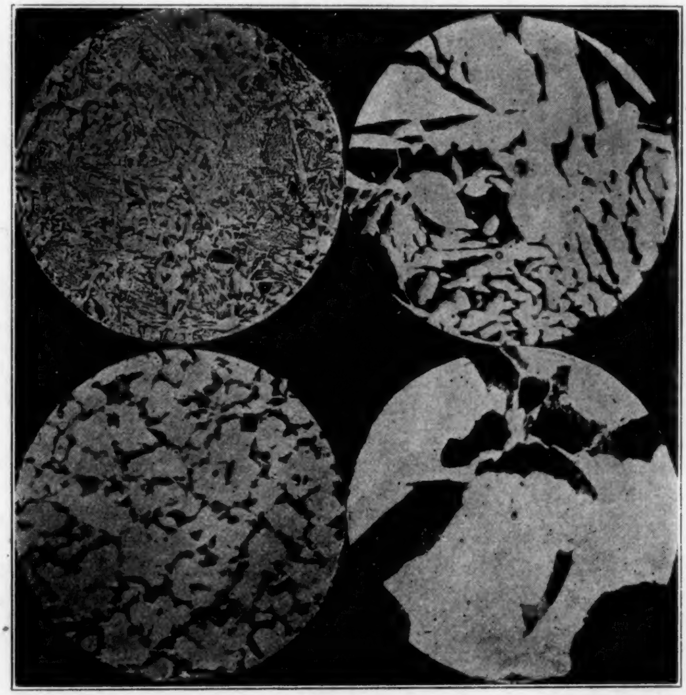

FIG. 8—UPPER LEFT, C 0.16, Si 0.36, Mn 0.98, AS CAST, X 30; UPPER RIGHT, SAME AS UPPER LEFT, BUT X 200; LOWER LEFT, SAME AS UPPER LEFT, BUT ANNEALED AND SLOWLY COOLED, X 30; LOWER RIGHT, SAME AS LOWER LEFT, BUT X 200.

cold after casting. By this means, and by careful and reasonably slow heating, to avoid sharp temperature potential between inside and outside, or between one part and another, it is usually possible to eliminate the risk of fracture. Obviously, the more brittle the cast condition of any particular type may be, the greater is the risk of mishap from this cause.

Although the microstructure may be perfectly changed from the coarse crystalline as cast condition to the finer, and less angular and consequently more ductile state by submitting the cast-

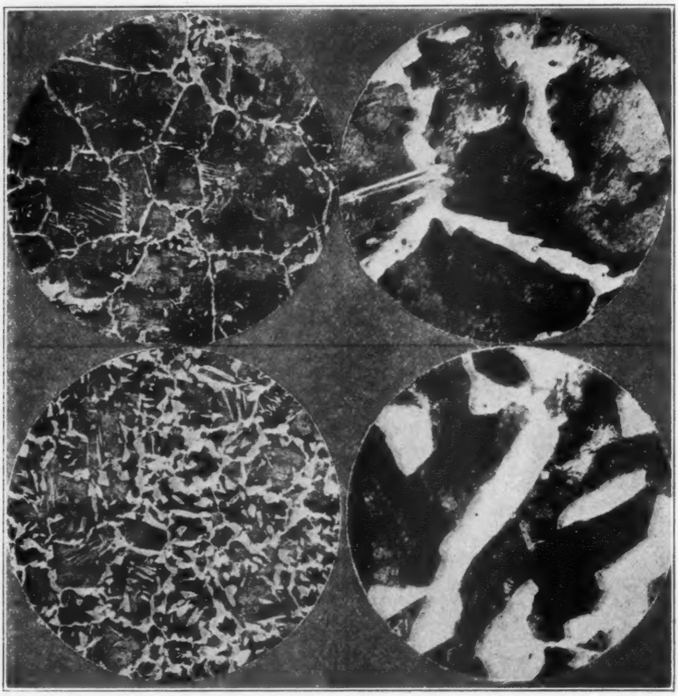

FIG. 9—UPPER LEFT, C 0.46, Si 0.30, Mn 0.81, AS CAST, X 30; UPPER RIGHT, SAME AS UPPER LEFT, BUT X 200; LOWER LEFT, SAME AS UPPER LEFT, BUT ANNEALED AND SLOWLY COOLED, X 30; LOWER RIGHT, SAME AS LOWER LEFT, BUT X 200.

ing to the correct temperature for a sufficient length of time, it is not necessarily in an unstressed condition. The bulk of the stress removal portion of heat treatment depends upon the cooling period. If this is so fast that section variation can cause material differences in temperature from part to part, unequal cooling stresses are bound to occur. In small castings their effect may be negligible, but in heavy castings it is essential that cooling is perfectly under control, and proceeds slowly and evenly. In some cases it is necessary that this is carried down at this rate to almost atmospheric temperatures, and serious fractures have been recorded when such castings have been removed from the furnace, at a period when the outside appeared to possess no noticeable degree of warmth.

A further feature associated with treatment, but only common in large complicated castings, is that of distortion. During the comparatively long periods these castings are at a high temperature there is always the possibility of distortion by sagging and very careful packing is necessary to ensure support.

Distortion can also be caused by uneven heating, and the writer has known long thin castings badly affected by one side being more exposed to the source of heat than the other.

The present paper does not claim to have exhausted by any means the possibilities of variation which exist in steel foundry practice, but has perhaps indicated sufficient to show that almost eternal vigilance is called for in the manufacture of steel castings if regularity is to be obtained and maintained. Some of the points raised may also indicate directions of investigations with a view to their elimination, or at any rate, the minimization of the frequency of their occurrence.

The thanks of the writer are due to the directors of Messrs. Thos. Firth & Sons, Ltd., Sheffield, for permission to present this paper, and also to the principal of the Brown-Firth Research Laboratory, Dr. W. H. Hatfield, for invaluable assistance with micro-photographs.

Note: Figs. 7 to 18 are typical micro-photographs of steel casting structures. All annealed samples have been slowly cooled

from annealing temperature, and are therefore representative of heavy type castings normally treated in this manner. A shorter period at full temperature followed by a quicker cooling, such as is common to lighter castings, would have produced much finer structures.

Sand Control and Sand Conservation in a Gray Iron Jobbing Foundry

By T. F. Kiley,* Providence, R. I.

Abstract

This paper deals with: Sand tests, testing and reclamation as conducted at foundries of Brown & Sharpe Mfg. Co. Value of sand tests as found in control, conservation and reclamation. Standards established for various floors and types of sand. Methods of reclamation, difficulties met with in rebonding spent sands and methods used for overcoming. Various mixtures of reclaimed sand used in light and heavy foundry. Shop testing as a means of determining relative values of bonding clays. Silt formation in and rate of drying out of reclaimed sand mixtures. Effect of drying and exposure to high temperatures on strength of clay treated reclaimed sand as compared to a natural sand.

Introduction

This paper will deal with the value of sand tests as the writer has found them in keeping heaps throughout the shop in a satisfactory condition, the rebonding of spent molding sand with clay and some experiences in using and trying out the relative values of various clays as a means of conserving sand.

Foundries located close to the source of satisfactory molding sands and to whom the problem of doing away with spent sand is unknown may not be particularly interested in usage of clay for this purpose but most foundries are not fortunate enough to be classed in this group. Blending of sands and clays to produce a sand most suited for one's own particular use is being practiced quite extensively. Sands produced in this manner sometimes have physical properties difficult or impossible to duplicate in natural

*Metallurgist, Brown & Sharpe Mfg. Co.

sands. These blended sands are often particularly adaptable for certain classes of work.

With present-day competition, particularly among jobbing foundries, any information bearing on cutting of costs is of interest. Large quantities of molding sand are used in the course of a year. The bill is large in any event, but often it may be very considerably reduced by bringing into use knowledge gained from testing of sands and adopting methods of reclamation where feasible.

Where a foundry is engaged in one class of work, and where sands used may be of one or two grades, conservation and control of sand is possibly a more simple matter than in a jobbing shop where several grades of sand may be in use and are being mixed more or less in reclaiming. How one foundry uses reclaimed sand without ill effects on castings and methods of so doing will be described.

The company with which the writer is associated has used clay in the rebonding of spent molding sand since June, 1925, shortly after which time sand tests were adopted as a guide to the proper use and treatment of this material.

Conflicting opinions were advanced on the use of rebonded sands, molders looked askance at it, unquestionably there were pitfalls to be avoided in its usage and it seemed imperative to have some means of testing so as to have an impartial report as to the condition of a sand heap. Fortunately tests perfected by Sand Research Committee of the American Foundrymen's Association and other investigators were available and it was only necessary to select the tests which seemed most suited for our purpose. On investigating the various methods used in the testing of foundry sands an attempt was made to select the simplest and most rapid methods of testing thought accurate enough for routine control.

Tests and Methods of Testing

Tests used in our shop control on foundry sands are relative moisture, permeability and bonding strength. Occasionally, where further information is wanted, sand samples are sent to a local

laboratory for fineness, actual moisture or dye adsorbtion determinations. These qualities are investigated on some new sands that are received, or on occasional check up on fines accumulating in reclaimed sand. These cases are comparatively few, however, and it seems to be more advantageous to send such samples outside where this information is wanted.

All heaps, about 125, are tested at least once a week for moisture, permeability and bond. Facing sands and light foundry reclaimed sands are tested daily, and new sand is tested when received. Heaps found off are reported and checked the following day. Heaps are inspected daily for temper by feel and if a heap seems off temper a test is made of that heap in addition to the weekly test. With weights of castings running from an ounce up to 3 tons neither permeability nor bond change rapidly enough to make more frequent testing necessary. This method enables the detection of any deterioration in a heap before bad castings result.

The moisture test does not give a daily record of moisture in heaps, but along with the feel method is an additional check on the tempering gang and aids in keeping moisture within proper limits. Then, as moisture vitally affects permeability and bond, a moisture test is necessary in determining these characteristics. In measuring moisture we use the Dietert[1] indicator, which depends on the principle that the height of a test core rammed with a specified weight of a certain grade of sand varies inversely as the water content.

Testing Equipment

Fig. 1 shows a photograph of apparatus used in testing of sands, which is mounted on a desk table. (A) is the standard A. F. A. rammer. (B) machined slotted disk which fits snugly into the specimen tube and is used to insure straight draw when removing core from tube; (C) Dietert relative moisture indicator; (D) metric scales for weighing sands; (E) compression testing machine for determining bond; (F) scale, family type, either reading to 24 lbs. by ounces or to 60 lbs. by two ounces

[1] H. W. Dietert and W. M. Myler, "Molding Sand Control in the Foundry," 1926 Transactions A. F. A., Vol. 33, pp. 751-753.

with pan on platform to receive core as it crushes; (G) standard A. F. A. permeability apparatus with orifices for making rapid permeability determinations.

Fig. 2 shows a close up view of the compression strength machine, with (H) a steel disk for receiving the core as it is forced from tube and upon which is part of a test core which has been tested for strength by compression.

Method of Testing Sample

A specified weight of a certain type of sand is weighed into a pan, so shaped as to permit the sand to be transferred to permeability tube without spilling. The sand after being placed in the tube is given the regulation ram, moisture is read from indicator and if it is within the specified limits for that sand, the permeability is determined in the usual manner, mainly with fine

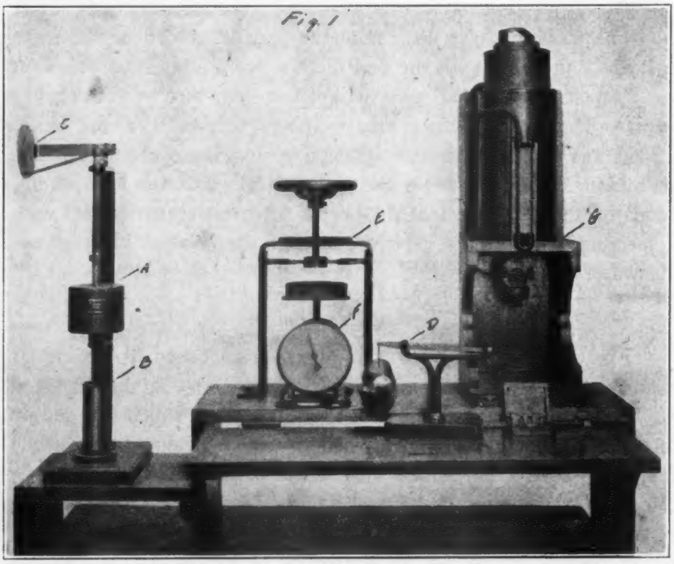

FIG. 1—COMPLETE APPARATUS FOR ROUTINE CONTROL OF FOUNDRY SANDS

orifice. The tube with the sand specimen is then placed on the steel disk (H) Fig. 2 and transferred back to rammer. The weight and rammer head are lifted, the tube and disk placed under the rammer head, which is gently eased into the tube with the operator holding back on the weight so as not to ram further. The machined disk is fitted into the top of the tube and operator using one hand to hold down on the rammer rod above weight, the other hand snaps the tube up, leaving the core intact on steel

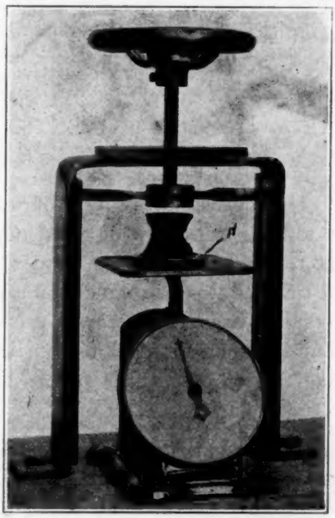

FIG. 2—CLOSE UP VIEW OF COMPRESSION TESTING MACHINE

disk. The core resting on the steel disk is then placed in the pan on the platform of scale (F). The hand wheel is turned and the core compressed. The needle on the dial is watched and a reading taken as the core crushes.

The crushing strength reading divided by 3.1416 equals the compressive strength in pounds per square inch.

The core, unless it is a very strongly bonded sand, crushes as in Fig. 2 which has had loose sand removed from sides of stand-

ard 2 inch core. Six determinations each on two samples of sand are recorded in Table 1.

By means of the apparatus described tests of relative moisture, permeability and bond are made in 3 to 5 minutes' time per sample. Generally all three determinations are made on one

Table 1

COMPARISON OF RELATIVE MOISTURE AND COMPRESSIVE STRENGTH

Sand: Heavy Foundry Facing			*Sand:* Light Foundry Reclaimed		
Sample No.	Relative Moisture	Compressive Strength lbs. per sq. in.	Sample No.	Relative Moisture	Compressive Strength lbs. per sq. in.
1	4.2	4.5	1	4.7	3.6
2	4.2	4.3	2	4.7	3.6
3	4.1	4.2	3	4.6	3.6
4	4.1	4.4	4	4.7	3.6
5	4.1	4.5	5	4.6	3.6
6	4.2	4.4	6	4.6	3.6

rammed sample. If, however, a sand is off on temper this is recorded, but the sand is wet down or dried out to come within certain limits that represent an average temper and a sample of adjusted sand is rammed to determine permeability and bond. Temper may be rapidly adjusted for testing by laying sand out on paper and running hands through it when wet, or by adding water and working through sand until proper limits are reached where dry.

On taking up sand tests a study of the various heaps in light and heavy foundry were made and records made of relative moisture readings, permeability and bonding strength when heaps felt right and were producing satisfactory castings. In this way standards were established for determining these physical characteristics, such a weight of sand is taken so as to bring a sample of average temper within the tolerance marks on rammer. This will explain why for some sands we may use as low as 160 grams and on others as high as 190 grams.

Table 2 gives standards for our foundry sands when they have the best working properties. Fig. 3 shows approximate actual moisture obtained by standard drying out tests of one hour drying at 110 degrees Cent.

Value of Sand Tests

Foundrymen cannot always tell the physical characteristics of a sand heap by feel. The presence of coarse pebbles or grains will often lead him to believe that he has an open heap, whereas the presence of a relatively small amount of fines or silt will result in a close heap.

As a sand heap burns out or loses in bond a molder sometimes increases the water in an attempt to develop more bond and the heap feels better and this may lead foundrymen to believe that the bond is satisfactory until bad castings result.

Certain sands that feel close and give a fairly high fineness

Table 2

SPECIFICATIONS FOR FOUNDRY SANDS

	Floor Weight lbs.	Moisture Figure	Compressive Strength lbs. per. sq. in.	Permeability
Bench	170	3.5—5.5	3.5—5.5	11.0— 18.0
Squeezer	160	4.0—6.0	3.0—5.0	6.0— 14.0
Machine	175	3.5—5.5	3.5—5.5	18.0— 30.0
Side Floor	175	3.5—5.5	3.5—5.5	18.0— 30.0
Sand Slinger Facing	175	3.5—5.5	4.5—6.5	20.0— 40.0
Regular Sea Coal Facing	175	3.5—5.5	4.5—6.5	20.0— 40.0
Light Foundry Reclaimed	175	4.0—6.0	4.0—6.0	12.0— 18.0
Sand Slinger Heap Sand	185	4.5—5.5	3.5—5.5	40.0— 80.0
Fine Albany	155	5.0—5.6	3.5—5.5	6.0— 12.0
Fine Molding	160	4.5—5.0	3.5—5.5	10.0— 16.0
Medium Molding	175	3.5—5.5	4.0—6.0	25.0— 40.0
Red Key	175	3.5—5.5	3.0—5.0	60.0— 90.0
Jersey Green	185	4.0—6.0	3.5—5.5	40.0— 60.0
Wareham	160			100 —200
Provincetown	190			200 —300
Providence Fine Core	150	4.6—6.0	0.5—2.0	100 —

Machine floor heaps made up of fine Albany sand test out as for squeezer floors.
Squeezer floor heaps made up of medium sand test out as for machine floor.

number may be high in permeability and quite open due to the fact that there is very little material left in screen test on the finer or coarser mesh sieves; that is, the sand is of uniform grain size, producing smooth surface on castings without sacrificing permeability.

Sand tests give the foundryman the correct answer in such cases as these; other desirable features are:

a. The condition of sand pile is adjusted before reaching the point where bad castings result.

b. Removes molder's alibi that the sand condition is responsible for defective castings due to improper molding methods.

c. Saves time, effort and material in investigations as to the causes of certain defects in castings, eliminating the factor of sand and enabling immediate concentration on other factors that might have a bearing. The writer has seen varying mixtures of new and old sand tried in attempts to stop a certain defect which was finally overcome by change in gating or method of molding.

d. Makes possible a record of physical characteristics of sand that have produced best results on certain jobs and makes duplication of these characteristics possible.

e. Provides ready guide in blending of sands to acquire a sand mixture best adapted for certain type of work but not readily obtainable.

f. Aids in conservation of sand by preventing new sand

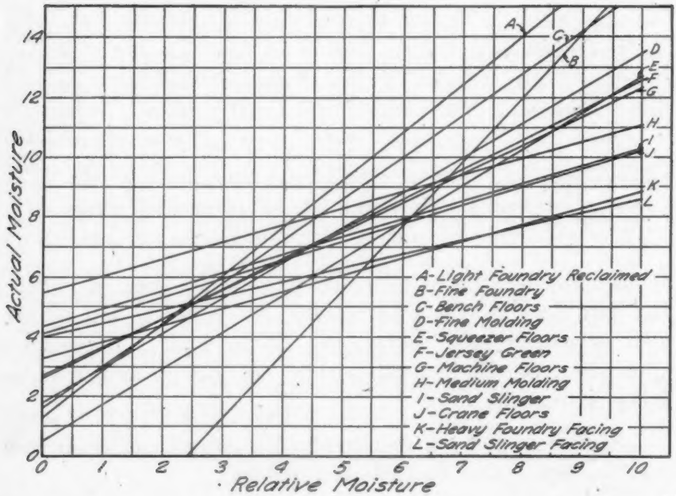

FIG. 3—CHART SHOWING RELATION BETWEEN RELATIVE MOISTURE AS DETERMINED BY DIETERT RELATIVE MOISTURE INDICATOR AND WITH STANDARD DRYING OUT TESTS AT 110 DEGREES CENT.

additions until physical characteristics are such as to make this advisable. Tests show that often it is possible to go for extensive periods without new sand additions, particularly where facing sand is used. Adding new sand by time intervals instead of by change in physical characteristics seems a faulty method of keeping up heaps. In a jobbing foundry, at least, the class of work is changing constantly. Naturally, when castings are heavier the bond burns out faster, and when castings are cored to a greater extent the rise in permeability due to unavoidable core droppings is more rapid. Chunky work, with bond burning out faster, results in faster accumulation of compound grains in heap also, raising permeability and affecting fineness of sand.

g. Tests are also ready means of judging new sands and establishing specifications so that they will be furnished uniform.

Conservation of Sand

During June, 1925, experiments on a small scale were started with a brand of clay to determine the possibilities of reclaiming gangway sweepings and sand which had been burned out to such an extent as to make it unfit for use. Trial heaps were made up consisting of spent sand and clay, also of facing sands of the same materials with sea coal addition. After an experimental period of from three to four months the conclusion was reached that it was possible to use such sand on a great deal of the work without any ill effects on the castings. In October, 1925, the practice of discarding spent sand was discontinued. This has resulted in a very considerable decrease in amounts of new sand required.

Sands used in our light foundry are No. 00 Albany for squeezer floors, No. 0 Albany for benches and some machine floors, and also No. 2 Albany for certain machine and bench jobs. Sand that used to be rejected from these floors and containing more or less core droppings is taken to a sand mixing unit, there screened, the batches measured out, a certain percentage of clay added and the mixture then mulled for about 4 minutes, tempered and aerated. This sand is returned to the light foundry for use on other than squeezer floors, or for use on side floors in the heavy

foundry on certain jobs requiring a smoother surface than that obtainable with side floor heap sand or using regular heavy foundry facing. As this reclaimed sand is a mixture of 3 sands containing core droppings it cannot be used on work requiring an extremely smooth surface obtainable only by using an extremely fine sand such as No. 00 Albany or No. 0 Albany.

The light foundry reclaimed sand mixtures are made up in 836 pound batches.

By volume they are 29¼ part light foundry spent sand and ¾ part clay. By weight they are 98 per cent spent light foundry sand and 2 per cent clay.

An expensive very colloidal bentonite clay is used in above mixture. Using other bonding clay the mixture is:

By volume 28 parts light foundry spent sand and 2 parts clay. By weight 94 per cent light foundry spent sand and 6 per cent clay.

Spent sand from the heavy foundry made up of varying mixtures of coarser Jersey sands and medium molding is brought to sand mixing unit screened, clay and sea coal added, then mulled, tempered and aerated as for light foundry sand.

The heavy foundry reclaimed sand mixtures (facing) made in 980 pound batches are by volume 25¼ parts heavy foundry spent sand, 3 parts sea coal, 7 parts Provincetown (N. E. Silica), and ¾ of a part clay.

By weight they are 77.5 per cent heavy foundry spent sand, .5 per cent sea coal, 20.0 per cent Provincetown (N. E. Silica), and 2.0 per cent clay.

Bentonite clay is used in the above mixture. Using other bonding clays the mixture is:

By volume 24 parts heavy foundry spent sand, 3 parts sea coal, 7 parts Provincetown (N. E. Silica), 2 parts clay.

By weight they are 73.5 per cent heavy foundry spent sand, .5 per cent sea coal, 20.0 per cent Provincetown (N. E. Silica), 6.0 per cent clay.

The Provincetown sand is of uniform grain size, high in permeability, conveniently located and is used to keep up permeability on heavy foundry facing. Wareham core sand up to 20 per cent has been added to offset permeability decrease in light foundry reclaimed sand but this is very seldom found necessary. The mixture of spent sands when rebonded results generally in a sand a little coarser than 0 Albany, which is satisfactory for grade of work where used.

Method Used in Trying Out Bonding Clays

Trial batches are made at the muller with all spent sand and clay until a batch is obtained having physical characteristics considered suitable for work that is to be tried out in the heap. A heap of about four tons is made up and given to a molder on side floor work. The heap is tested every few days, over about a thirty-day period, and results on the castings noted. Where the molder runs short of sand due to sand being carried away on castings more of the same material is added. Tables 3, 4, 5, 6 and 7 give a record of tests on five clays designated as clays A, B, C, D and E. The first three are Penna. clays, the fourth a Bentonite and the fifth a Vermont clay.

Drying Out of Reclaimed Sand

Occasional complaints from the foundry were to the effect that heaps and molds made up entirely of clay treated spent sand dried out more rapidly than natural sand heaps, giving molders difficulty in keeping heaps at right temper, and that in patching molds this sand did not seem to have the water absorbing qualities of a natural sand and that, on adding water in patching, the treated area had a tendency to become muddy rather than damp, and that molds sometimes were difficult to patch due to being weak or crumbly in the dry state. Tests on the rate of drying out and tests when on bond air dried were made in an attempt to throw some light on this phase.

Clay A is a very colloidal bentonite clay. Clay B is a high fusing clay. Facing sand and light foundry reclaimed sand was made up using each clay; test cores were rammed, and relative

Table 3
CLAY—*a*

	Actual Moisture per Cent	Permeability	Compressive Strength lbs. per sq. in.
Refuse Sand before Rebonding	5.23	19.0	2.1
Refuse Sand after Rebonding with 5 per cent Clay	6.54	15.7	6.2
After 2 days' use	6.70	17.3	6.3
After 5 days' use	7.04	20.0	4.7
After 8 days' use	8.10	20.0	5.0
After 10 days' use	6.70	20.0	4.1
After 12 days' use	6.96	23.4	3.8
After 14 days' use	7.20	24.2	4.4
After 16 days' use	6.68	25.8	3.6
After 18 days' use*	7.46	20.0	4.2
After 21 days' use	6.96	19.0	3.5
After 27 days' use	6.90	19.0	3.0

*Ten per cent of same material added here.

Table 4
CLAY—*b*

	Actual Moisture per Cent	Permeability	Compressive Strength lbs. per sq. in.
Refuse Sand before Rebonding	2.94	14.7	0.5
Refuse Sand after Rebonding with 6 per cent Clay	5.32	10.0	3.5
After 2 days' use	...	12.2	3.5
After 6 days' use	...	12.2	3.8
After 9 days' use	6.10	13.0	3.3
After 15 days' use	6.34	14.7	4.0
After 19 days' use	6.00	13.8	3.8
After 25 days' use*	6.76	13.8	3.8

*Ten per cent of same material added.

Table 5
CLAY—*c*

	Relative Moisture per Cent	Permeability	Compressive Strength lbs. per sq. in.
Refuse Sand after Rebonding with 6 per cent Clay	4.9	18.4	5.0
After 3 days' use	5.4	17.8	4.5
After 4 days' use	5.0	16.7	5.2
After 9 days' use	4.5	19.0	4.8
After 18 days' use	5.4	19.0	4.5
After 23 days' use*	5.5	20.0	4.6
After 33 days' use	5.0	24.2	4.5

*Ten per cent of same material added here.

Table 6
CLAY—*d*

	Relative Moisture per Cent	Permeability	Compressive Strength lbs. per sq. in.
Refuse Sand before Rebonding	4.4	19.5	3.0
Refuse Sand after Rebonding with 2 per cent Clay	4.0	19.5	4.8
After 2 days' use	5.0	17.8	4.5
After 6 days' use	4.9	19.0	4.1
After 9 days' use	4.7	19.5	4.4
After 12 days' use	4.4	21.0	4.4
After 15 days' use	4.8	21.8	4.1
After 18 days' use*	4.0	20.0	4.5
After 21 days' use	4.8	21.0	4.5
After 24 days' use	4.7	22.7	4.5

*Started using facing sand on certain jobs here. Facing made with same clay.

Table 7
CLAY—*e*

	Actual Moisture per Cent	Permeability	Compressive Strength lbs. per sq. in.
Refuse Sand before Rebonding	5.14	14.7	1.7
Refuse Sand after Rebonding with 6 per cent Clay	9.00	9.4	5.0
After 1 day's use	6.78	9.4	4.8
After 7 days' use	7.50	9.4	4.4
After 12 days' use	6.94	10.0	4.5
After 17 days' use	6.80	10.7	4.3
After 21 days' use*	6.24	10.7	4.0
After 27 days' use	5.96	10.0	4.0
After 32 days' use	5.86	10.7	3.7

*Ten per cent of same material added here.

Table 8
MIXTURES A-1 AND B-1 BEFORE HEAT TREATING

Mixture A-1
25¼ Parts Refuse Sand
3 Parts Sea Coal
¾ Parts Clay A
7 Parts Provincetown Sand

	Per Cent
Relative Moisture	5.0
Actual (Chart) Moisture	6.0
Permeability	36.0
Compressive Strength, lbs. per sq. in.	8.0

Mixture B-1
24 Parts Refuse Sand
3 Parts Sea Coal
2 Parts Clay B
7 Parts Provincetown Sand

	Per Cent
Relative Moisture	5.0
Actual (Chart) Moisture	6.0
Permeability	34.0
Compressive Strength, lbs. per sq. in.	6.9

Table 9
AIR DRY FOR 2 HOURS—3 TEST CORES ON EACH

	Mixture A-1			Mixture B-1		
Initial Relative Moisture, Per Cent	4.7	4.6	4.7	4.7	4.6	4.7
Actual Per Cent Moisture (Chart)	5.9	5.8	5.9	5.9	5.8	5.9
Final Relative Moisture, Per Cent	3.6	3.4	3.6	3.0	2.8	3.0
Final Actual Per Cent Moisture (Chart)	5.3	5.2	5.3	5.0	4.8	5.0
Loss in 2 Hours, Per Cent Moisture	0.6	0.6	0.6	0.9	1.0	0.9

Samples A-1 and B-1 exceeded limit of 25-lb. scale in strength after drying 2 hours.

Table 10
MIXTURES A-2 AND B-2 BEFORE HEAT TREATING

Mixture A-2
29¼ Light Foundry Refuse Sand
¾ Clay A

	Per Cent
Relative Moisture	4.2
Actual (Chart) Moisture	...
Permeability	14.7
Compressive Strength, lbs. per sq. in.	4.5

Mixture B-2
28 Light Foundry Refuse Sand
2 Clay B

	Per Cent
Relative Moisture	5.5
Actual (Chart) Moisture	...
Permeability	13.0
Compressive Strength, lbs. per sq. in.	4.2

Table 11
AIR DRY FOR 12 HOURS—3 TEST CORES ON EACH

	Mixture A-2			Mixture B-2		
Initial Relative Moisture, Per Cent	4.2	4.2	4.1	5.5	5.5	5.5
Initial Actual Per Cent Moisture (Chart)	7.8	7.8	7.8	10.1	10.1	10.1
Final Relative Moisture, Per Cent	3.4	3.5	3.5	4.6	4.5	4.6
Final Actual Per Cent Moisture (Chart)	7.4	7.4	7.4	8.6	8.5	8.6
Loss in 12 Hours, Per Cent Moisture	0.4	0.4	0.4	1.5	1.6	1.5

Samples A-2 and B-2 exceeded limit of 60-lb. scale in strength after drying 12 hours.

moisture, permeability and bond were determined. Additional cores were rammed and the relative moisture determined and the actual moisture interpolated from the chart. Then after air drying for stated periods these data were again determined and the loss in moisture noted. Results of this test are listed in Tables 8, 9, 10 and 11.

Practical results in the foundry and from the foregoing tests indicated that the character of clay has a considerable influence over rate of drying out of reclaimed sand. The more colloidal the clay, the less seems the rapidity of drying out of reclaimed sand. No apparent weakness in bond was developed with either of the clay treated sands on being dried for stated periods in so far as could be determined with the scales available.

As a check on the dry bond strength of reclaimed sand, standard test cores were rammed up from mixture A-1, mixture

Table 12

STRENGTHS OF MIXTURES AFTER BAKING FOR 8 MINUTES AT A TEMPERATURE OF 1600 DEGREES FAHR.

Mixture	Total Breaking Load in Pounds			Breaking Load, lbs. per sq. in.		
A-1	107*	128	163	34	40.7	51.9
A-2	242	285	259	77	90.6	82.4
Medium Molding Sand..	150	181	**	47.7	57.6	**

*Base of cylinder slightly broken.
**Cylinder broken upon delivery.

A-2 and new medium molding sand. As an extreme case of what a mold might be subjected to these were run through an annealing furnace attaining a maximum temperature of about 1600 degrees Fahr. for 8 minutes. All cores baked red and strong and were sent to a local laboratory to determine the strength on compression. The results are listed in Table 12.

The test indicated that clay treated sand bakes as strong as one of our natural sands used to a large extent on medium work; that a fine sand weaker in the green state than a coarser sand with the same amount of clay present in each case seems to bake considerably stronger than the latter, possibly due to less rapid destruction of clay bond in the fine sand.

Silt in Reclaimed Sand

In the experimental stage of trying out spent sand rebonded with clay, fineness and permeability tests were run on a trial heap to note what effect repeated use of a rebonded molding sand would have on grain size. Data from test results on a side floor heap, made up of spent molding sand rebonded with 5 per cent by weight of clay, are listed in Table 13.

Table 13

EFFECT ON GRAIN SIZE OF RETREATED USE OF REBONDED MOLDING SAND

	Per Cent Through Mesh No. 270	Fineness No.	Permeability
At Start	16.84	116	15.7
After 5 days' use	16.96	116	20.0
After 10 days' use	17.52	118	20.0
After 16 days' use	19.24	127	25.8
After 21 days' use	19.68	124	19.0
After 27 days' use	21.54	134	19.0
After 33 days' use	23.56	138	20.0
After 39 days' use*	20.74	132	19.0
After 44 days' use	20.40	131	20.0
After 48 days' use	21.18	130	20.0
After 54 days' use	19.38	126	21.8

*1400 pounds additional added to maintain size of heap.

The test indicated that fines or silt tends to accumulate in the heap and simply bears out the experience of many foundrymen on this point. The writer was interested particularly in the rapidity of silt accumulation. This brings up the question whether or not repeated use of reclaimed sand would not result in its going to a fine dust that would be worthless for molding purposes. The writer believes that this would happen if none of the sand was lost in casting, with the size of the heap remaining constant, with the same material used indefinitely, and no droppings from cores used.

No attempt is made to reclaim sand that adheres strongly to castings and which is removed at cleaning room. The addition of new sand to piles on lessening in quantity, sharp sand additions on rebonding, unavoidable core droppings in reclaimed sand, formation of compound grains in casting into sand; all these probably have their influence in preventing such an accumulation of silt as to cause concern.

After about two and one-half years of reclaiming, light foun-

dry reclaimed sand on screen tests shows 31.60 per cent passing 270 mesh sieve with a fineness of 167, practically the same as this material showed in initial stages and practically the same as fine molding sand No. 0 Albany new sand, used to large extent on floors where light foundry reclaimed sand is used.

After the same length of time, screen tests on heavy foundry facing shows 10.76 per cent passing the 270 mesh sieve with grain fineness of 90, which is more open than the facing formerly carried. A screen test on Jersey Green sand formerly used in ratio of 12 to 4 parts heap sand in making up facing shows 13.10 per cent passing the 270 mesh sieve with a grain fineness of 87.

Some Other Points Noted in Rebonding and Use of Rebonded Sands

It was found that the best method for distributing clay in rebonding was by means of the muller type mixer. Cutting clay through heaps with a sand cutter, as is practiced with new sand additions, frequently resulted in castings coming rough and pitted. These conditions probably were due to improper distribution of clay and also because larger quantities of clay had to be used in order to get satisfactory strength.

Coarse sands rebond more readily than fine sands. For example, facing sand, even with sea coal and about twenty per cent silica sand present with neither having any initial bond, shows a consistently higher bond than light foundry reclaimed sand, the clay additions being the same in each case. This is probably due to being more sand surface area to coat with clay in the case of the finer sand.

As brought out by Harrington, Wright and Hosmer in their 1926 A. F. A. paper,[2] there is a tendency toward sea coal accumulation. It was recently found necessary to reduce sea coal in facing sand from a ratio of 1 to 8 to a ratio of 1 to 11, for if the narrower ratio was retained the familiar veined appearance on surface of castings, associated with too much sea coal, would result.

Clay decreases permeability of sand on rebonding to an extent depending on the amounts of clay used.

[2] R. F. Harrington, A. S. Wright and M. A. Hosmer, "Practical and Technical Data Obtained from the Use of Clay Bond in Molding Sand Heaps," 1926 Transactions A. F. A.

Rebonded sands seem to increase somewhat in permeability and get coarser on using, probably due to clay baking on grains resulting in formation of compound grains[3] and to some extent due to core droppings or shot accumulation in heap. Removal of shot, remulling and rebonding seems to fine the sand down again. As a matter of fact facing sand would get entirely too fine without silica sand additions.

Facing sand or coarser sand shows a consistently lower moisture content than light foundry reclaimed sand. Finer sand carries a higher percentage of water without feeling wet, again probably a matter of greater surface area.

Light foundry reclaimed sand is distributed among various heaps in the light foundry as new sand. New molding sand is added occasionally so that no molder is working entirely with reclaimed sand though heaps have been used successfully for long periods on all reclaimed sand.

Troubles attributed to use of clay and rebonded sands in experimental stage were found on investigation to be due either to molding practice, improper mixing or some deficiency in temper, bond or permeability. When these conditions were corrected troubles ceased.

No unusual difficulty was noted in cleaning castings made in sand rebonded with the lower fusing, more colloidal clays and the life of this sand is apparently as long as higher fusing clays, as indicated in tests on side floor heap. The more colloidal clays seemed to give reclaimed sand more of the velvety feel of a natural sand, and the rapidity of drying out seems lessened on both heaps and molds. Higher initial permeabilities with the same strengths are obtainable with the more colloidal clays due to decrease in quantity used. It seems safe to assume that the less rapidly the drying out the better will the bonding agent withstand the heat action of molten metal which causes decomposition of clay bond, which decomposition of clay bond, according to some authorities, is responsible in certain cases for cuts, washes and scabs.

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[3] R. J. Doty, "A Study of the Change in Grain Size of Silica Sand Through Constant Addition of Clay," 1923 Transactions A. F. A., Vol. 30, pp. 782-795.

Sand treated with the higher fusing clays seems to take much more water than either natural sand or sands treated with more colloidal clays, without feeling wet or getting muddy. The very high colloidal clay treated sand takes very little water without getting muddy when the slicking tool is applied. Apparently in swabbing most of the water is absorbed near the surface and when a slight excess of water is present this is quickly brought to the surface by slicking. A molder has to be careful in the use of a swab when using sand rebonded with this type of clay.

Economies in Oxy-Acetylene Cutting for Riser Removal

By Glenn O. Carter,* New York

The oxy-acetylene cutting of risers is such an important part of steel foundry work that in the last few years it has had a fair share of attention. There are, however, many phases of the application where practices have not been standardized.

In many foundries one cutter is expected to take care of all in practically all foundries the cost per ton of product has been reduced in the last five years. On the other hand, the very ease with which risers and gates may be removed has resulted in increasing the cross section to be cut and this tends to increase the cost of cutting per ton of finished product.

Because cutting is a part of the manufacturing system it must go along in reasonably close step with the output just as the sand blasting or cleaning must be done. This puts a premium on "getting out" the work as compared with efficiency of cutting.

In many foundries one cutter is expected to take care of all work, but because the cost of the gases is much greater than the labor cost it may pay to aim for maximum efficiency rather than tonnage. The cost of gases for cutting steel five inches thick is approximately 8 times the labor cost and for steel ten inches thick it approximates 16 times. As thickness increases the ratio of gas cost and labor cost increases.

*Consulting Engineer, The Linde Air Products Company.

There is still another factor that enters into this problem of efficient cutting, yet the figures do not always appear in studies of cutting costs. The grinding of the castings to remove all traces of risers, gates and fins is another considerable item of cost, and closeness of cutting affects the grinding very materially.

Certain practices advocated by the author in a paper[1] read before your society several years ago are recognized as being just as suitable now. To supply oxygen and acetylene through pipe lines was then the practice in a few foundries. It is now general. Oxygen cylinders are connected to manifolds that are conveniently located for handling of cylinders. Acetylene is generated on the premises from calcium carbide and is supplied at suitable pressures up to fifteen pounds per square inch. (Never in excess of this for safety reasons.)

Connecting apparatus to single cylinders brought into the cleaning room is seldom done now because of the cost of extra handling of cylinders and the possibility of damaging cylinders from the moving around of castings.

More attention is now paid to equipment than was the case just after the war and attention is also paid to the use of correct gas pressures. Regulators attached permanently to pipe lines or at manifolds naturally do not give the trouble formerly experienced with regulators that were being shifted many times a week from one gas cylinder to another.

The attention paid to apparatus is another result from close attention paid to costs. Sudden rises in gas consumption per unit of work has pointed to defective cutting equipment, as was noted by R. W. Thomas of the Vulcan Iron Works in a paper read before The International Acetylene Association in 1925. This paper, by the way, included many other good pointers about cutting.

Another practice on which the seal of approval has been placed by many foundries is the separation of castings into groups according to size of risers, so that there will be a minimum changing of equipment and of pressures. No one blowpipe tip is suit-

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[1] *Managerial Study of Oxy-acetylene Cutting and Welding in Foundries*, Trans. A. F. A., Vol. 30, pp. 708-722 (1922).

able for cutting five inch steel and also either two inch or ten inch thick metal. A constant changing of tips is a waste of time and damages apparatus, although changing tips is cheaper than miscellaneous cutting with one tip.

The necessity for the proper welding tip is of course largely a matter of efficiency of the cutting operation, but it also greatly

FIG. 1—CUTTING RISERS OF ORDINARY SIZE

FIG. 2—OXY-ACETYLENE CUTTING CAN BE DONE IN PLACES DIFFICULT TO REACH WITH SAWS OR OTHER MECHANICAL METHODS

FIG. 3—CONTINUOUS RISERS OFFER NO DIFFICULTIES

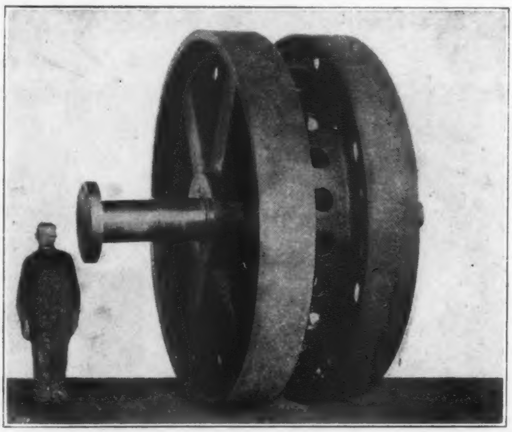

FIG. 4—GEAR CUT FROM BLANK SHOWN IN FIG. 3

affects the cost of cutting. Larger tips and higher oxygen pressures than normal will greatly increase the consumption of oxygen for the same thickness of cut.

In some places cutting blowpipes having different sizes of tips are kept hooked up so the change from one size to another is almost instantaneous. This is specially recommended where fins are cut, as they seldom require more than the smallest size of cutting jet.

The use of the oxy-acetylene cutting process has enabled designers of castings and the makers to undertake work hardly possible otherwise. This was well noted by Mr. Thomas in his paper, previously mentioned.

Larger risers and more pouring gates are now used than in earlier steel foundry practice because an ample reservoir capacity above the casting is essential to compensate for shrinkage and thus prevent pipes or blowholes. The foundry is in this way surer of getting a good casting than when small risers and gates are used. The location of risers is of importance in casting and, although it is advantageous to have risers so placed as to permit of straight cutting, this is not as essential with oxy-acetylene cutting as with mechanical cutting. Frequently such an excess of metal is used as to make continuous risers, like in cylindrical sections.

For cutting materials other than risers there are a few helpful suggestions that can be offered.

When the cut section is very extensive there is a heat effect that must be watched. Cutting with oxygen does not harm the metal if the cut is reasonably smooth, but the heat may cause warping. In these cases it will pay to heat slabs before shapes are cut out with the blowpipe.

Some study has been given to the use of machine operated blowpipes. So-called straight line cutting machines can be used without much trouble, and much of the operator's time is thus saved in cutting on work which is fairly heavy, such as ten inches and up. With machine control there is a decided saving in gases and the finished work should require a minimum of grinding. This phase of cutting requires the interest and study of the manager and the superintendent, and there may be a real reward for the effort.

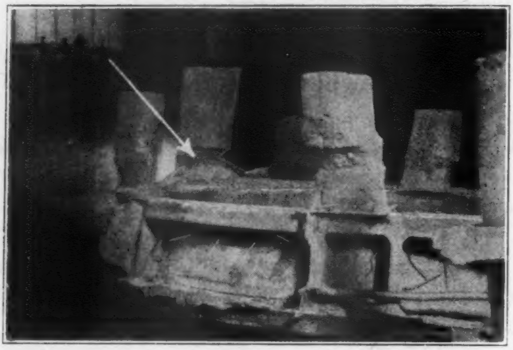

FIG. 5—OFTEN FINISHED CONTOUR OF CASTING CAN BE FOLLOWED CLOSELY—WITH IMPORTANT SAVINGS IN MACHINERY COSTS

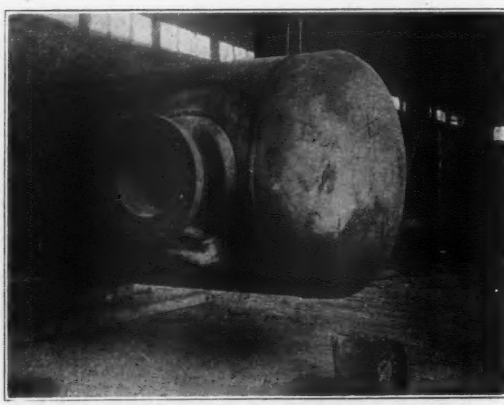

FIG. 6—AN EXAMPLE OF COMPOSITE CONSTRUCTION

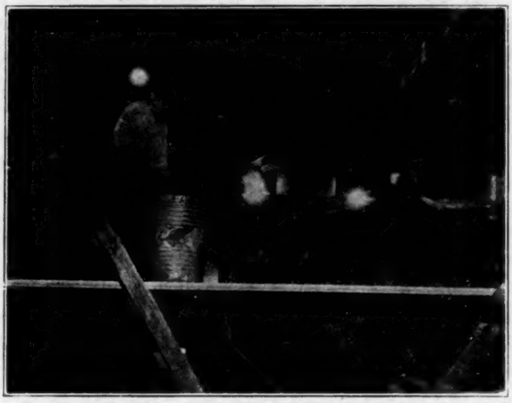

FIG. 7—WELDING CAST NOZZLE TO HEAVY STEEL PLATE

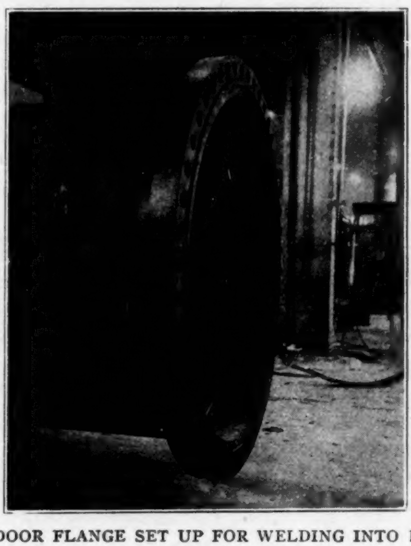

FIG. 8—CAST DOOR FLANGE SET UP FOR WELDING INTO HEAVY STEEL TANK

Another application of the oxy-acetylene process has had further study in the not distant past. The welding of defects in iron and steel castings is quite an item in all foundries. One way of facing this is so to limit the use of welding that the repaired section will not be subjected to stress. This will allow of very low grade workmanship for mere filling in operations but it is not in accord with present tendencies in other directions in welding.

There is the alternative of using oxy-acetylene welding as a strength element. The steel foundries have not come to this use in any such way as some of the gray iron foundries have. The splendid description of oxy-acetylene welding installation at certain automobile engine casting foundries give details as to correct practices for use of welding as a strength carrying detail.

It may be that the steel foundries have not come to a full appreciation of correct welding practices beginning with qualifying of operators, the use of suitable high grade filler materials and the use of adequate preheat.

The recent article by R. A. Bull, "When Should Steel Castings be Welded," gives a cue as to a clever and suitable way of testing workmanship. It is certain that the expense of testing is offset by the reduction in other costs. Adequate checking of welding certainly repays the management wherever welding is used.

The use of the oxy-acetylene weld as a structural element is of growing importance to the steel foundryman on the side of developing or holding business.

High grade steel castings can be and are being joined to pipe and plate steel by oxy-acetylene welding so as to give a finished product better than can be made by use of pipe or plate alone. The reason is that very simple, therefore, dependable castings can be made to give adequate thickness of metal at points of maximum stress. Then relatively thin sections of rolled steel can be used at high working stresses where the section would be too thin or too complicated for satisfactory castings. Two examples of this are given in Figs. 6, 7, and 8, just to point the way, but many other cases of this use have occurred.

Oxidation Phenomena During the Annealing of Malleable Cast Iron

By H. A. Schwartz,* Cleveland, O.

Abstract

The present paper contains no original data. It constitutes an attempt to correlate the researches of Schenck and others with commercial annealing conditions and to outline what may be expected to happen under various circumstances as to composition of furnace gases and temperature.

It is shown that the surface metal of malleable castings is strongly influenced by variations in these conditions and that therefore the machineability of the product may in large measure be determined by annealing conditions.

No attempt is made to discuss methods calculated to produce particular effects and a study of the paper will show why well known precautions are successful rather than suggest new procedures.

The oxidation phenomena during annealing are important industrially because of their relation to machineability. This arises from the fact that in general machining operations as commercially carried on in this connection remove only a relatively thin surface layer of metal and hence the machineability of a casting is largely a function of the characteristics of the metal within, say, one-sixteenth inch of the surface. Now the condition of this surface metal is determined both by the original composition of the casting and the changes produced in that composition by the action of the gases which surround it during the annealing process. The matter is further complicated by the fact that changes in the gas composition affect not only the composition of the surface layers of the metal but also the rate of the graphitizing reaction.

The writer will not in this connection dwell at much length

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on the latter subject, which has been previously discussed before this Association.[1]

All commercial annealing takes place in atmospheres which represent the oxidation products of carbon by air or by oxygen from packing materials. The composition of the atmosphere of

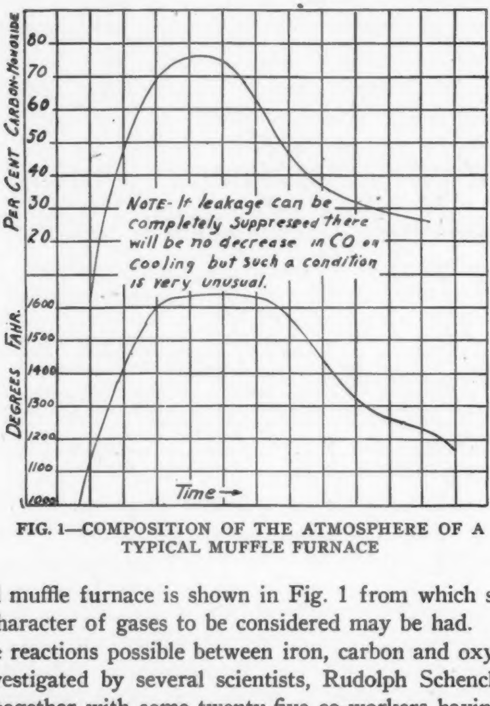


FIG. 1—COMPOSITION OF THE ATMOSPHERE OF A TYPICAL MUFFLE FURNACE

a typical muffle furnace is shown in Fig. 1 from which some idea of the character of gases to be considered may be had.

The reactions possible between iron, carbon and oxygen have been investigated by several scientists, Rudolph Schenck in particular, together with some twenty-five co-workers having studied the problem intensively for twenty years or more.

The data of this paper as to the equilibria involved are taken from Dr. Schenck's most recent summaries of his investigations.[2] The equilibria involved are shown in Fig. 2, which may require

[1] Hayes and Scott, *The Catalysis of the Graphitization of White Cast Iron by the Use of Carbon Monoxide Carbon Dioxide Mixtures When Applied Under Pressure*, Trans. American Foundrymen's Association (1925), Vol. XXXIII, pp. 574-593.

[2] Schenck, *Gleichgewichtsunterschungen über die Reduktions, Oxydations- und Kohlungsvorgänge beim Eisen*, V. Zeitschrift für anorganische und allgemeine Chemie, Vol. 167, p. 315.

some explanation. Two lines are shown, marked C and Fe_3C respectively, which represent the gas compositions in equilibrium with free carbon and cementite respectively. The former marks the ratio of CO to $CO + CO_2$ at which the reaction

$$2\,CO = C + CO_2 \quad (1)$$

does not proceed in either direction.

For combinations of temperature and composition above and to the left of this line the reaction (1) proceeds toward the right

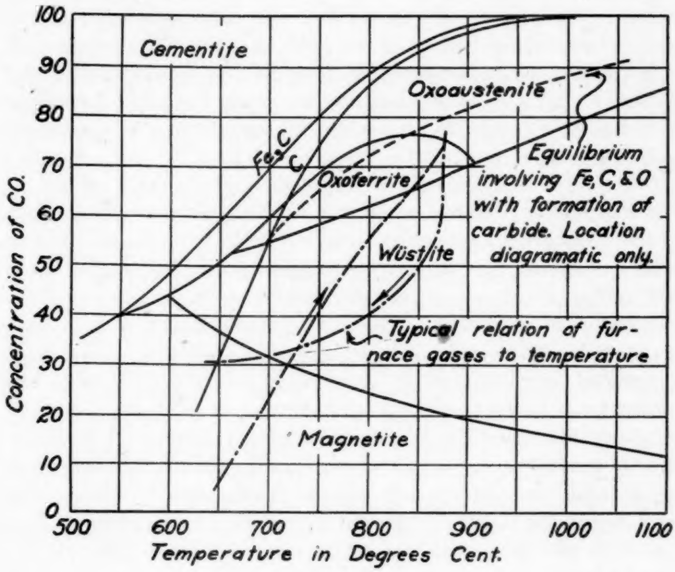


FIG. 2

and vice versa. The latter marks the equilibrium condition for the reaction

$$2\,CO + 3\,Fe = Fe_3C + CO_2 \quad (2)$$

and what was said of (1) may, *mutatis mutandis,* be said of (2).

Now it is evident, incidentally, that in the narrow band between the lines C and Fe_3C the reaction (1) proceeds toward the right and (2) toward the left so that the net result is the reaction

$$Fe_3C = C + 3\,Fe \quad (3)$$

the gas phase not experiencing, necessarily, any permanent change of composition until no more cementite remains. This is the mechanism of the Hayes experiments whose major value was that they invited attention to an earlier error of Schenck which the latter himself detected and corrected. Be it noted that any gas composition between these two lines does not in the presence of both C and Fe_3C constitute equilibrium but is merely an accidental balance between the rates of two reactions.

The chart is further subdivided by lines dealing with the reaction products of the gas on iron. In the space between any two of these lines some compound of iron is stable, the name of that compound being inserted in the figure. It appears well established that iron uncontaminated with oxygen can not exist in the presence of CO or CO_2. It was long known that CO oxidized manganese according to some reaction such as

$$4\ Mn + CO = Mn_3C + MnO$$

but this was not believed to be true of iron. It now appears that either CO or CO_2 will react with ferrite to form what Schenck calls oxoferrite, that is, iron containing some small and variable percentage of oxygen in solution either as the gas or as FeO. Oxoaustenite is similarly a solid solution of carbon in iron contaminated with oxygen. The field marked "Wüstite" refers to a compound long believed to be identical with ferrous oxide but shown by Schenck to contain other oxygen in solution. The field marked "Magnetite" is of obvious meaning, being that in which Fe_3O_4 is stable. Except in so far as the presence of oxygen in oxoaustenite, oxoferrite, and Wüstite is necessary to explain certain departures from the normal iron carbon equilibrium and to reconcile the facts with the requirements of the phase rule the reader may substitute mentally for oxoferrite, iron; for oxoaustenite, austenite; and for Wüstite, ferrous oxide without introducing any serious misunderstandings.

On the boundary line between the oxoferrite and Wüstite fields a reaction approximating, but not exactly equal to

$$Fe + CO_2 = FeO + C \quad (4)$$

proceeds in neither direction. Above the line that is in the oxoferrite field it proceeds to the left and vice versa. With suitable changes the same may be said of the line between Wüstite and magnetite for the equation

$$3\ FeO + CO_2 = Fe_3O_4 + CO \quad (5)$$

The diagram is nominally correct for atmospheric pressures, that is, it assumes that the sum of the partial pressures of CO and CO_2 is one atmosphere. If, as is usual, nitrogen is present, the partial pressure of $CO + CO_2$ is to the total pressure as the sum of their volumes is to the total volume. The reactions take place as though the nitrogen were absent and the pressure correspondingly reduced. A reduction of pressure moves the C and Fe_3C curves to the left, leaving the lines which separate the various iron-oxygen phases unaltered.

Since in what follows we are concerned qualitatively with the ultimate results only, it may suffice to point out the existence of these variations without attempting a still more exhaustive consideration of the work of Schenck. Let us now consider what applications such a diagram has in connection with the annealing process.

Either equation (1) or (2) will obviously remove carbon from iron if the concentration of CO is less than that corresponding to the C and Fe_3C lines for the existing temperature.

The commonly existing decarburized rim of malleable castings results from one or the other of these reactions. Many have investigated the carbon content of malleable castings at various distances below the surface. Some typical curves resulting from such investigations are shown in Fig. 3. Whether the castings were "framed" or not is noted in the figure but the reader is cautioned against any assumption that a particular form of curve is associated with a framed fracture. The curves of Fig. 3 have been selected to show a limited number of definite types and in the original material from which the selection was made there is no such relation.

The curves differ essentially in the carbon concentration at the surface, with regard to the depth below the surface at which the maximum or original carbon is reached, and with regard to the location of the zone of minimum carbon concentration, which is usually, but not always, at the surface. There are also some interesting curves in which there are zones of constant carbon content whose further consideration is not entirely within the province of this paper.

Let us now proceed to a correlation of the material so far at hand. Suppose we insert a piece of hard iron into an air filled

container at say 900 degrees Cent. (1650 degrees Fahr.). Reaction (2) will at once take place; (1) can not for there is as yet no free carbon to burn. Also there will result Fe_2O_3 or Fe_3O_4 from the reaction of oxygen on metallic iron. There will come a time, however, when all the oxygen is combined with either carbon or iron. So long as CO is not present in a concentration less than that corresponding to the upper boundary of the magnetite field at 900 degrees Cent. the iron will oxidize to magnetite,

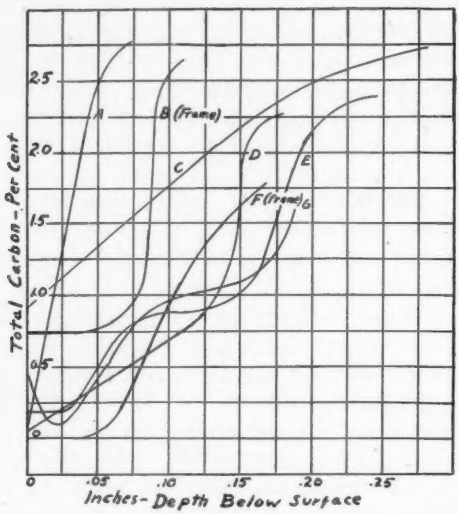


FIG. 3

CURVE A—SLIGHT DECARBURIZATION OF THIN SURFACE LAYER ONLY. SLOPE OF INITIAL PORTION OF LINE DUE ENTIRELY TO LACK OF PARALLELISM OF SAMPLING WITH ORIGINAL SURFACE.

CURVE B—DEEP UNIFORM LAYER OF CARBON CONTENT IN EQUILIBRIUM WITH GAS PHASE, UNIFORM IN THICKNESS BY VIRTUE OF RAPID MIGRATION OF CARBON IN METAL.

CURVE C—SIMILAR TO A, FLAT CARBON GRADIENT NOT EXPLAINABLE UNLESS BY MIGRATION OF GAS IN METAL.

CURVE D—SURFACE LAYER NEARLY CARBON FREE IN EQUILIBRIUM WITH GAS RICH IN CO_2. CARBON GRADIENT RISES TO EQUILIBRIUM WITH Fe_3C ABOUT ONE-EIGHTH INCH IN. GRADIENT STEEPER THAN B BECAUSE OF LOWER SURFACE CARBON.

CURVE E—DEEP DECARBURIZATION SIMILAR TO B FOLLOWED BY CHANGE OF COMPOSITION OF GAS TO ONE IN EQUILIBRIUM WITH CARBON FREE IRON ONLY.

CURVE F—SURFACE DECARBURIZED COMPLETELY BY GAS. ASCENDING BRANCH OF CURVE PERHAPS DISTORTED BY SAME CAUSES AS A. F REPRESENTS A LONG CONTINUATION OF CONDITIONS GIVING A ON SHORTER EXPOSURE.

CURVE G—SIMILAR TO E FOLLOWED BY CHANGE OF GAS PHASE OR DROP OF TEMPERATURE PRODUCING RECARBURIZATION AT SURFACE.

causing a layer of scale. Such a layer can not, however, persist, for any gas in equilibrium with magnetite will burn C as such or as cementite so that if carbon be available the oxygen will leave the magnetite and combine with carbon. The magnetite will become successively Wüstite and oxoaustenite, provided only that no new oxygen is supplied and that carbon is available.

If the temperature be somewhat lower, say 800 degrees Cent. (1470 degrees Fahr.), the magnetite may ultimately be reduced under these circumstances to oxoferrite. The result will be that there is a layer of nearly pure iron (or of nearly pure austenite) which has been formed from a layer of iron oxide and is not therefore an integral of the casting but a more or less adherent skin which may be capable of removal from the casting and cause the defect called "pealing," rather uncommon in this country but apparently an important source of difficulty abroad. It results as shown when the gas phase changes from one in the magnetite or Wüstite field to one in the oxoferrite or oxoaustenite field due to the combustion of the carbon of the metal or indeed from any other cause.

Obviously since we do not wish our castings to remain covered with oxide we can not expose them, at least for any appreciable time, to conditions of temperature and gas composition below the upper boundary of the Wüstite field or they will "scale" as the shop term goes. The same precaution will prevent "pealing" for "pealing" can not occur unless after the formation of a scale. If annealable castings are held sufficiently long in a sufficiently limited amount of any mixture of CO and CO_2 they will become graphitized and consist of carbon, a solid solution (boydenite) of iron and carbon in equilibrium therewith and the gas phase will be in equilibrium with both and have a composition dependent on the temperature as shown by the line C of the diagram. Under such circumstances the surface layer of metal will have a carbon concentration corresponding to the maximum solubility of carbon in iron (contaminated with oxygen) at the temperature in question. If the metal is then cooled in a time insufficient to permit any material amount of carbon migration the surface of the final casting will be fairly high in carbon, which may be graphite or pearlite dependent upon the graphitizing conditions.

Now if the $CO\text{-}CO_2$ ratio is maintained by some outside influence at some definite ratio situated within the oxoaustenite field the outer layer of metal will have some particular carbon content, less than saturation, depending upon the particular gas phase and higher, the higher the $CO\text{-}CO_2$ ratio. If the composition falls into the oxoferrite field the surface layer will be free from carbon or if it falls into the Wüstite field it will be an iron oxide. The depth of decarburization will depend upon the time available. The composition of the surface layer having attained substantial equilibrium with the gas phase under appropriate conditions at a concentration lower than the maximum solubility of carbon in (oxo) austenite there will be a constant outward flow of carbon from regions where excess cementite or carbon is present toward the surface. If the rate of migration of carbon in iron is great and the decarburized zone thin it may even be that carbon is not oxidized at the surface as rapidly as it is brought up by migration, but as the zone widens there will always be a time at which migration is slower than oxidation and the equilibrium value of carbon will be reached at the surface.

Should the gas composition change in the direction of more CO or the temperature fall, the surface will recarburize accounting for the condition in which the surface layer of metal is higher in carbon than one further in. It is also possible that in some cases decarburization may take place to a point around one per cent of total carbon before any graphitization has occurred. Graphitization will then be initiated with great difficulty and, especially on cooling below A_1 it will proceed only very slowly because of the infrequency of graphite nuclei, and a pearlitic rim will be the consequence. The use of packings, which is now decreasing, is an instance of the unconscious application of these equilibria.

In the early days of the art it was always desired to decarburize the casting. This was not practicable in an open flame, for the castings would have been badly scaled.

Most packings were somewhat impure iron oxides contaminated accidentally with sand and clay which on heating became in turn complex silicates of iron. Every such chemical compound has a particular gas composition in equilibrium with it which will not be altered so long as the material for reaction is available.

Now it is known by actual experiment that the packings which scale castings are in equilibrium with gases richer in CO_2 and poorer in CO than the composition marked by the upper boundary of the Wüstite field. Packing materials which are in equilibrium with gases richer in CO than these values will oxidize carbon but not iron and would therefore decarburize metal but not produce an oxide layer on the surface. Their oxygen combines with carbon, forming a gas in equilibrium with the packing which is relatively plentiful and of large surface and this reaction would go on indefinitely so long as carbon and oxygen remain but the CO_2 concentration will not alter.

When ore used to be added to packing this was always done sparingly, the rationale being that unless this ore disappeared as a separate ingredient early in the heating, the gas in equilibrium therewith would at once produce scale.

The special form of the curves showing the carbon content at various depths below the surface is worthy of some mention, although the major considerations of this paper deal only with the carbon content at the surface. They are brought about, as elsewhere touched upon, by a combination of the rate oxidation and of migration of carbon. Nominally they approach a type represented by a band sometimes wide, sometimes narrow, having a nearly constant carbon concentration followed by an abrupt increase to nearly the original carbon content.

Neither carbon nor Fe_3C migrate as separate phases, but only in solid solution. After the reaction has gone on for a little time there will be a layer whose outer surface has a carbon content in equilibrium with the surrounding gas and whose inner surface is in contact with imbedded carbon or Fe_3C, these inclusions, which were originally in this boundary zone, having been oxidized by the process to be described.

Carbon will then flow outward across this zone and be burned at the surface of the casting. The inside surface of the decarburized zone is thus impoverished in carbon to the point at which it can dissolve more carbon or Fe_3C, which it does, thereby increasing its own width and the zone widens in proportion as time goes on. The abrupt rise is due to the fact that since the migration is in solution none will take place unless there exists a difference of concentration in the solution. No such differences can exist so long as an excess of carbon or Fe_3C is present.

In the areas from which these constituents have not been removed completely the solid solution is of constant carbon concentration and migration is prevented.

What has been said suffices to show that normally the carbon content should be that in equilibrium with the existing gas atmosphere at the surface, that corresponding to the solubility of carbon at a depth below the surface, depending on the time and the original value of total carbon at all points further in.

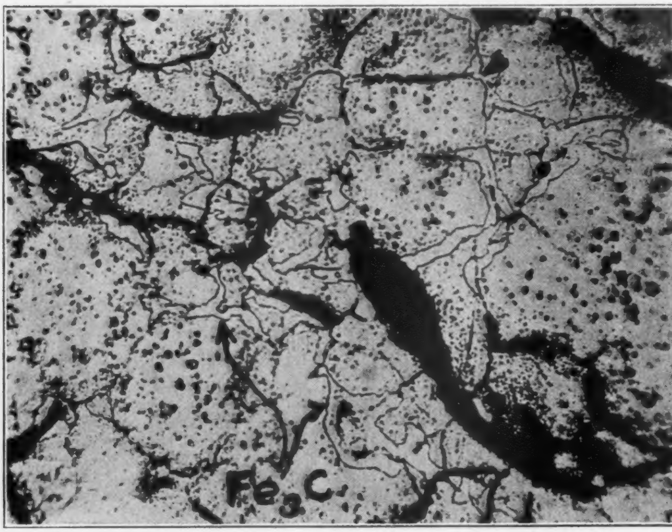


FIG. 4—CEMENTITE IN OXIDIZED ZONES OF MALLEABLE IRON. BLACK VEINS ARE IRON OXIDE APPROXIMATING FeO. WHITE ISLANDS AS MARKED, CEMENTITE. LIGHT GRAINS CONTAINING GRAY SPECKS, FERRITE, SHOWING ETCHING PITS ON ACCOUNT OF DEEP ETCHING. MAGNIFICATION, 500 DIAMETERS BY C. H. JUNGE IN THE AUTHOR'S LABORATORY

Since the advancing front of the decarburized zone is probably not always parallel to the surface of the casting due to various irregularities of structure and since it is impossible to remove layers for analyses of absolutely even thickness, the sharp changes of composition which should be present are somewhat smoothed out under observation.

Changes of composition of gas may cause secondary changes

in the carbon distribution in the rim either by recarburizing the surface to a point where inward migration begins or by further decarburizing a surface after a wide decarburized band has been established, resulting in some cases in an approximately constant carbon for some distance outside the undecarburized core followed by a steep gradient downward to the surface. This condition should be most prevalent when the initial concentration of carbon at the surface is nearly that representing the concentration

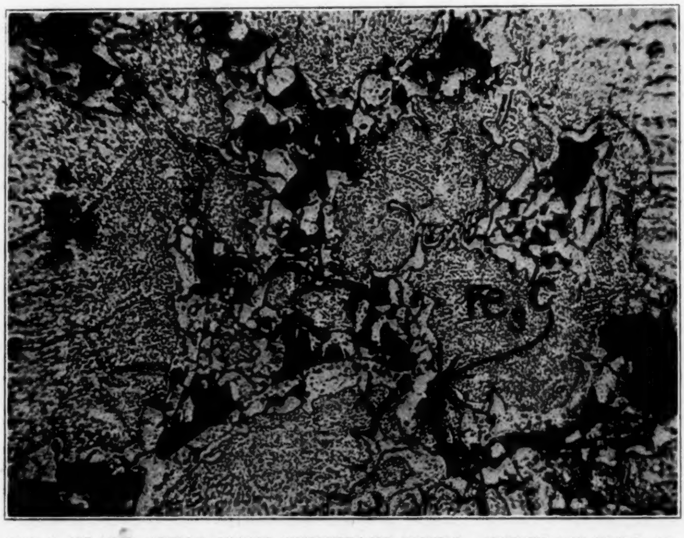


FIG. 5—BLACK AREAS MARK SHRINKAGE VOIDS. WHITE ISLANDS AS MARKED, CEMENTITE. LIGHT GRAINS WITH DARK SPECKLES, FERRITE, SHOWING ETCHING PITS ON ACCOUNT OF DEEP ETCHING. MAGNIFICATION 500 DIAMETERS BY C. H. JUNGE IN THE AUTHOR'S LABORATORY

of the saturated solid solution. Note also that any gas phase of higher concentration than this will produce no decarburization unless the gas actually diffuses into the iron.

It is well here to refer also to another phenomenon not yet clearly worked out. Many observers have found an equilibrium line located about like the dotted line of Fig. 3. Schenck himself once found such a line which he regarded for some time as being

that representing reaction (2). It is now known that it represents a more complex equilibrium, not yet definitely defined, but involving the transformation of oxidized iron into Fe_3C. It will be noted that its location is on the opposite side of line C from line Fe_3C. It follows that under these circumstances, Fe_3C is stable with respect to carbon and hence that if the condition repsented by the dotted line is established graphitization will cease. This may be another explanation of the persistence of certain pearlitic rims, the stabilization of the cementite being due to the absorption of oxygen by the metal.

The presence of oxides is not very unusual in the surface of malleable castings and demonstrates that heat treatment occurred under temperature and atmospheric conditions falling in the Wüstite area. The oxides never exist except in layers which were completely decarburized at one time. Such oxidized areas frequently contain grains of cementite as shown in Fig. 4, which probably result from the reaction of oxygen bearing iron with CO. The oxidation of shrinks during cooling in the mold, which takes place readily because of their porous structure, is perhaps a cause of the persistence of Fe_3C in such zones as shown in Fig. 5. Occasionally massive cementite is seen in the surface of a casting which evidently is not a residuum of some of the original carbide. This also may arise from the carburization of a somewhat oxidized iron layer at the surface of a casting.

It has been the writer's purpose to show how, by applying the available data as to equilibrium conditions in the system Fe-C-O we may explain many of the phenomena which, occurring at the surface of castings, renders their machining difficult. No operating suggestions are possible except in the form of generalizations which follow naturally from the preceding discussion. Obviously, if we know the conditions producing certain results, we may avoid the results by avoiding the conditions. It is no doubt unnecessary to point out to foundrymen familiar with malleable production the machining characteristics to be expected.

Reports of Apprentice Training in Foundry Centers

Foundry Apprenticeship in Pittsburgh

By C. D. Carey,* Pittsburgh, Pa.

A distinctive feature of apprentice training in the industries of Pittsburgh is the excellent understanding which exists between the shops and the public schools. Fifteen trades in all are co-operating with the public schools in the training of apprentices. The young men who are learning trades are divided into two classes. The beginners in each trade are co-operative students at the schools, that is, they spend alternate periods of two weeks at trade work and two weeks in school in the study of subjects which are related to the trade which they have chosen. These co-operative apprentices work in pairs, so that there is always one at school and one on the job.

The purpose of this co-operative work is to make the young men thoroughly familiar with the work and the conditions of the trade. When they have spent sufficient time at co-operative work of this kind to demonstrate their interest in the trade and their ability to pursue it successfully they are transferred from the co-operative class to a regular, full time indentured apprenticeship and are given credit for the work which they have done on a co-operative basis.

*President, Pittsburgh Foundrymen's Association.

This plan of training has been adopted by the Pittsburgh Foundrymen's Association, comprising about seventy foundries in the Pittsburgh district. For several years our foundries have been training young men successfully in co-operation with the public schools of the city. A new trade school is being built which is to include as well equipped a school foundry as it is possible to build and which will enable us to give our apprentices the best training possible. Our foundrymen are very enthusiastic about this enterprise and are giving it all the support that they can.

The shop work of the co-operative students is devoted to those regular foundry operations which are fundamental in the trade and which will serve as a basis for carrying on the more difficult work of the regular apprentice course. The school time is devoted to four main branches:

Foundry mathematics
Foundry technology
Foundry drawing
Foundry economics

The mathematics course includes study and practice in those calculations which the foundryman and the foundry operator is required to perform as a part of his regular work. Foundry technology is concerned with the technique and the practice of melting, molding, core making, cleaning, annealing, sand preparation and handling and other information which the foundryman requires. Foundry drawing is intended primarily to impart facility in reading of blueprints and foundry economics has to do with the business and administrative side of the foundry industry and of industry in general.

This general plan of apprentice training has been in effect for two years and in that time the number of corporations participating has grown from 12 to 27. The number of part time apprentices has grown from 56 to 130 in the same time, while the full time apprentices have increased from none at all to 52.

Of the total of 182 part time and full time apprentices, there are 40 in the foundry, 17 in the pattern shop, 50 in the machine shop and 22 in the drafting trade. The remaining 53 are scattered over 11 other trades.

The general plan of apprenticeship has a number of advantages which experience has amply demonstrated. In the first place,

the schools play a vital part in the system and the school authorities are intensely interested. Through the schools the trades have been brought close to the pupils and as a result there has grown up in the community a distinct trade consciousness and an appreciation of the importance of industry in the community. Boys take trade work seriously and the trades have a dignity in the schools which could not easily be built up under another system. Again, by this arrangement it is possible to make a careful selection of boys for apprentice training. The teachers have the boys in their care for a long period and as they have the industrial viewpoint they can make extremely intelligent suggestions and criticisms. Finally, the work of the apprentice is most carefully supervised.

However, this is not the only system of apprentice training in the community. In fact, there are really three distinct systems. In addition to the plan which has been described, the Union Steel Casting Company has, during the last four years, trained apprentices in all departments of the foundry. According to this company's plan, the apprentices spend their entire time in the plant and are given related trade instructions in a plant school. They are placed under the direction of a supervisor who is both a practical molder and foundryman and a teacher qualified to teach the related trade work which forms a part of the apprentice training program. The practical apprentice work is done during the first five days of the week, while Saturday morning is devoted to class-room work.

During the first six months of their apprentice course, the apprentices are members of a beginners' class, where they are taught the fundamentals of molding work and the making of simple cores. The first three months of this beginners' class constitutes a probationary period, after which the contract is signed if both the boys and the employer are satisfied that the apprenticeship can be continued successfully.

After the apprentice has completed the beginners' work, he is given floor work in green and dry sand of all sizes, including sweep work. A thorough training in core making is also included.

During the entire apprenticeship course the young man is in charge of instructors or supervisors and at no time is he under the jurisdiction of journeymen foremen. A full record of work

is kept, as well as of the personal characteristics of the apprentice, including attendance, ability, neatness, industry, dependability and other qualities which are of importance in industrial work.

A third successful system of apprenticeship is conducted in the Pittsburgh district by the Mesta Machine Company. This system is unique in that the period of apprenticeship is determined by the ability of the apprentice. Provision is made for a maximum apprenticeship period of 10,800 hours, divided into eight periods of approximately six months each. At the end of the probationary period of three months, the apprentice is graded in attendance, deportment, progress in shop work and school work. Class A apprentices are given a credit of 25 per cent of the maximum time or 1,350 hours for the period. Class B apprentices are given 12½ per cent credit and Class C apprentices are given no credit. At the end of each period the apprentices are regarded in order to determine the length of time which they will be required to serve in the next period. In this manner, a Class A apprentice is able to serve his entire apprentice course in seventy-six hundred and ninety-eight hours, or slightly over three years.

Another feature of the Mesta system is that the apprentice is not required to serve more than a total of four and a half years in case the working hours are shortened, due to slack times.

A quarter or half hour interview, in which a careful general estimate of the applicant's qualifications are made, an examination in elementary mathematics and a physical examination are the main factors in the selection of apprentices for the foundry course, as well as for others.

Apprentices are usually started in the core room or on small and medium work in molding. They start as molder's helpers and gradually are given more and more complicated work to do by themselves. The course provides work on stock cores, bench and floor core making, helping molder in green and dry sand and a full year devoted to medium and large molding work. A period of pattern making and pattern repair work is also included. The entire program is carried out under the supervision of apprentice instructors.

Apprentice school work is conducted at the shop and includes mathematics, drawing or blueprint reading, trade technology and economics. Not all apprentices are able to cover the entire course

during the four years of apprenticeship but most of them can. An apprentice who does good shop work but cannot keep up in his studies is not dropped for this reason, because shop work is, after all, the most important feature of the work. However, those apprentices who do well in school work have a higher rating and build up the standard of men in the shops. Lectures on different phases of foundry work and industry are given to the apprentices once a month on Company time.

Careful records are kept of the work done by the apprentice, the rate increases and the school work completed. A record is also kept of the grades given the apprentice by shop superintendents in order to determine the length of time he is to serve in the next period, as already explained.

Although the apprentice training work in Pittsburgh has only begun, we feel that the beginning has been excellent. One thing has been accomplished which other communities who have been training apprentices for years are still striving for and that is a favorable sentiment among the people of the city for the trades and trade work for young men. With this great problem overcome, we hope to make still more rapid strides in the future.

Further Apprenticeship Possibilities in An Organized District

Report on the Milwaukee District Situation

The so-called Milwaukee plan of apprentice training is based upon the idea that all the manufacturers in a district or community are jointly responsible for the training of sufficient skilled men for the district and giving the young men of the community an opportunity to get into industry under the best possible conditions.

The National Metal Trades Association in Milwaukee includes the leading operators of machine shops and foundries in the district. These manufacturers have organized to carry out the district training idea, just as manufacturers frequently organize for advertising, for research, for legislation and for similar purposes. They have accepted the responsibility for training the mechanics and experts who are required in their own shops.

This organization of manufacturers for apprenticeship is based on certain fundamental ideas. For instance, a real apprentice training program must be an actual training process and not an exploitation of young men. Industrial apprenticeship must become a vital educational factor in the community and must take its place, side by side with the schools, as a preparation for life work. The apprenticeship agreement should be drawn up in a formal document or contract. Adequate supervision of apprentices must be provided by every manufacturer who trains young men. The apprentice training work should be carried on in cooperation with the city schools and other civic agencies having to do with young people and the idea of apprentice training must be kept before the people as much as possible.

In carrying out these ideas, the Metal Trades manufacturers have standardized certain features of apprenticeship, such as the number of hours in the courses, the approximate rates of pay to be paid to apprentices in various trades, the trades in which ap-

prentice training is to be established, the providing of appropriate school instruction and others.

The apprentice training activities have been in charge of an apprenticeship committee of the Metal Trades Association for years. The present committee was appointed in 1921. In 1926 the committee was reorganized and two committees were formed, a general and an operating apprentice committee. The general apprentice committee comprises five executives and officers of corporations who determine policies and exercise general supervision. The actual work is done by the second committee of fifteen or twenty members made up of apprentice supervisors and personnel men, which committee reports to the general committee and accomplishes its purpose by means of meetings for the discussion of apprenticeship and meetings of apprentices for various purposes, apprenticeship banquets, contests, such as the American Foundrymen's Association molding and pattern contests, published data on apprenticeship and a program of local publicity and education.

The work of this committee has not been in vain. As a result of its consistent efforts, the number of apprentices in the Metal Trades Association shops of Milwaukee has grown steadily from year to year. In 1905 there were 217 apprentices registered, by 1921 this number had grown to 460. At the present time there are between 900 and 1000. The following table indicates the growth in numbers in various trades during the last five years.

	Foundry	Machine	Pattern	Co-operative	All Others	Total
1923	73	303	96	129	303	704
1928	150	368	114	152	121	905

W. J. Fairbairn, secretary of the Metal Trades Association in Milwaukee, has estimated that about 15 per cent of all employees in the shops are highly skilled mechanics, the type of men an apprentice training course should produce. He also has statistics which indicate that skilled mechanics spend about eighteen years at their trade on an average. Accordingly, one-eighteenth part of the skilled mechanics in the Metal Trades shops will need to be replaced every year by apprentice graduates. As far as the members of the Metal Trades Association alone are concerned, the normal loss of skilled mechanics per year in all trades is almost

equalled at the present time by the number of apprentice graduates per year as shown here.

	All Shops in District	Association Members	Apprentices
Total employees	30,000	18,892	905†
Skilled employees	5,100	2,833	...
Skilled employees lost per year (18th part)	280	156	147‡

†Total apprentices. ‡Last-year apprentices.

Of course, the problem is by no means solved. In the first place, this development has been attained only within the last year or two and there is a deficit of mechanics to be made up which has accumulated during many years in which apprentice training was inadequate. Again, it has not yet been possible to determine that the 147 apprentice graduates in their last year are properly distributed into the various trades of machinist, molder, pattern maker, draftsman and others according to the requirements of these various trades. It may be possible that the number of machinists included in the 147 is more than the Metal Trades shops require per year, while the number of molders included in the figure may be less than are required.

The greatest apprenticeship problem which still remains to be solved in the district is the supply of mechanics for machinery building shops who are not members of the Association and who have done very little in the matter of apprenticeship so that a considerable portion of apprentice graduates from the member shops gradually find their way as mechanics into plants in which no effort is made to train skilled men. The total employment in machinery building industries of Milwaukee, both members and non-members of the Metal Trades Association, is in the neighborhood of 30,000, of which about 5,100 are highly trained mechanics and the normal loss of skilled mechanics per year is about 280, or one-eighteenth part of total skilled mechanics. The number of apprentices in shops not belonging to the Metal Trades Association is neglible and the 147 apprentice graduates in Association shops per year is clearly inadequate to replace the normal loss in the district of 280 mechanics per year.

Finally, there are still a few members of the Metal Trades Association who have not begun the training of apprentices. These comprise thirteen shops employing a total of 1,840 people. The general situation can be well summed up as follows:

	Number of Shops	Total Employees	Number of Apprentices
Association members and training apprentices.....	33	17,051	903
Association members and not training apprentices..	13	1,841	None
Not members of association......................	154	11,906	Negligible

Mention was made a moment ago of the possibility that the number of apprentice graduates in the district are not properly divided among the various trades. A study of the situation in the foundry trade of the district indicates that this is the case. Of 5,355 foundry employees in shops of the Metal Trades Association about 650 are highly skilled mechanics. Accordingly, the normal loss per year should be about 35 molders. Since the turnover among foundry apprentices is considerably higher than in other trades, the 152 foundry apprentices in Metal Trades shops will by no means include 35 apprentices about to graduate at all times. Accordingly, there is room for expansion in foundry apprenticeship in Metal Trades Association shops. This does not take into account the foundries in the district which are not members of the Association, which employ about 400 skilled mechanics and in which no apprentices are being trained.

In spite of progress which has been made, two great tasks still remain. In the first place, the total number of apprentices and the number of apprentices in the various trades must be brought to the point where the number of graduates per year will equal the normal annual loss of skilled mechanics, both in total and in each trade. In the second place, the burden of apprentice training must be distributed equally among all manufacturers in the district who profit by the enterprise, regardless of whether they are members of the Association or not.

Very definite plans have already been made for the solution of these big problems. A year ago a survey was made of members of the Metal Trades Association who did not train apprentices in order to find what difficulties stood in the way. After the survey was completed it was found that every single one of the difficulties given had already been solved in some shop and a program of papers and discussions was arranged in which manufacturers who had overcome these difficulties explained how it was done. Thus, the argument that apprenticeship in the small plant was impracticable was answered in a paper by a manufacturer who had never employed more than fifty men in forty years and had always had apprentices.

This program was arranged in connection with a dinner of

members of the Association and executives in Association shops. The meeting was well attended and each difficulty under discussion was thoroughly thrashed out.

As a result of the meeting a very considerable enthusiasm for apprentice training developed and the operating apprenticeship committee took advantage of the situation and enlisted the services of a special committee for the introduction of apprenticeship in those shops in which nothing had been done. The personnel of this committee is such that an appeal can be made to any type of man in industry who might be approached on the matter of apprentice training. It comprises a retired manufacturer, a vice-president, a works manager, a plant engineer and an apprentice supervisor.

During the past year this committee has been very active and has achieved excellent results. Its activities have been confined for the present only to plants which are members of the Metal Trades Association. After a year's work they can point to three shops in which apprentices have been taken on and to five others in which the preliminary surveys and preparations are under way and in which apprentices will be employed within a very short time.

The methods of the committee have been well thought out. An individual member of the committee calls upon a manufacturer regarding the matter of putting on apprentices in his plant. The matter is discussed at some length and the committee member makes a note of the manufacturer's objections. Thereupon his problems are discussed by the committee as a whole and solutions are worked out. In a second visit the committeeman presents these solutions as well as he can. If he fails to get results by himself he calls upon other members of the committee to go with him for a third visit.

By this means it is hoped to win all members of the Association to apprentice training and later on to reach out to manufacturers who are not members. In fact, in Milwaukee, the apprenticeship problem centers almost entirely about the manufacturers. The idea of apprenticeship has been so well established in the community that more boys apply for apprentice training than can be accommodated. In one large plant in the district only 44 foundry apprentices were engaged in 1927, although many over a hundred made application for foundry work.

Foundry Apprenticeship in Oakland

By H. L. Martin,* Oakland, Calif.

We have become quite interested in apprenticeship in the East Bay Foundrymen's Association of Oakland, partly as a result of the efforts made by the American Foundrymen's Association to bring this important question to our attention. A number of our recent meetings have been devoted exclusively to a discussion of the possibilities of apprenticeship in our district and it is more than possible that the interest which our members are now taking in the question may bear fruit before a very great length of time has passed. I shall briefly review the apprenticeship situation as it exists in our district.

In the first place, it is important to explain that our foundry industry in Oakland, and indeed on the Pacific Coast in general, has not been developed to the extent that it has been in mid-western and eastern centers. Sometimes we read about foundry districts in which there are thousands of employees in the industry or of individual foundries which employ several thousand men. In Oakland there are only a very few foundries, less than a dozen, although the population of the city is well over a quarter of a million. And these foundries are mostly very small, some of them employ less than a dozen men all told. Accordingly, we have an unusual problem to solve and methods which have been successful in other districts will not necessarily apply in our Association. This will make some of you smile, I suppose, because I am told that this is a much overworked argument, brought forth by every manufacturer who does not wish to bother with apprentices and feels that there are peculiar circumstances in his particular plant by which he is exempted from this responsibility. However, do not mistake me, I mention this circumstance not in order to escape the duty of apprenticeship but to explain that we may need to go about it in a way that is different from what has been done in other districts.

We realize full well that if our foundry industry is to survive

*Secretary, East Bay Foundrymen's Association.

and prosper we must constantly have a young generation of foundrymen who can succeed to important positions as they become vacant. We realize also that the foundry industry is not obviously attractive. The fascinating features of founding evolve themselves only after a considerable length of time at the work. American young men will fight shy of this industry unless definite measures are taken to make it attractive to them. We realize that some formal and organized procedure must be followed in attracting young men to our industry and we believe that apprenticeship is the best solution of the problem.

In preparation for making this report I visited eight of our leading foundries. In three of these foundries there is a total employment of forty-six men and of this number five are apprentices. In four of these foundries no apprentices are employed. In our own shop, the foundry with which I am connected, we have seven apprentices. One of these is in the pattern shop, one is in the core room and the remaining five are molder apprentices.

Our apprentice course for molding covers a period of four years and is arranged in six month work periods as follows:

1st Period—Labor work and molder's helper.
2nd Period—Second molder in charge of an experienced and competent mechanic.
3rd Period—Molding machine operation of various kinds.
4th Period—Molding machine operation of various kinds.
5th Period—Core room, sweeping up, finishing and core making.
6th Period—Core room, sweeping up, finishing and core making.
7th Period—Jobbing work on the floor.
8th Period—Jobbing work on the floor.

During the first period of six months or period of probation every foreman in the shop passes upon the boy to determine his capability for foundry work, and the boy is given an opportunity to determine by actual contact whether or not he wishes to make foundry work his occupation or life work.

During the fourth or last year of apprenticeship the boys are placed in charge of a gang of two or three molders, they are given responsibility for the work in hand and it is up to them to organize the work to get results with the men under them. In this manner we test for ability as straw bosses and foremen and give the boys an opportunity to display ingenuity in handling intricate jobs of various kinds.

Although school work has not been made a compulsory part of our apprentice training, the boys are given all reading matter on foundry work and operations which it is possible to obtain and they are encouraged to attend excellent evening classes which are taught in local educational institutions.

Although the pay of the apprentices may be adjusted by the superintendent, depending upon their ability and upon conditions otherwise, a pay schedule has been adopted as follows:

1st Year—$3.75 per day
2nd Year—$3.75 per day
3rd Year—$4.50 per day
4th Year—$6.00 per day

After graduation, apprentices are occasionally encouraged to work in other plants in order to get a wider experience, and return after a year or so to continue their work.

The general situation in the Oakland foundry district appears to be that foundry owners favor apprenticeship and foundry operators or managers are not so much interested. Foundry owners feel that apprenticeship could be worked out if sufficient attention were paid to it, that there are sufficient boys of the right calibre who could be interested in apprenticeship, that the grade schools are developing boys of the type who are needed for this kind of work and that the foundry industry owes it to the community and themselves to train a young generation of workers for the industry. The operators or managers, on the other hand, complain that boys are hard to find, that they usually leave before they have served their time and go to work for somebody else who has spent no effort upon them and that the entire apprenticeship plan is not worth while.

It appears that one great difficulty is the fact that many of our foundries provide no real training program. Boys are engaged as apprentices and are expected to learn the foundry business, but they are left very much to themselves. No apprenticeship agreement is drawn up, no program of work laid out, no schedules of pay are provided, there is no adequate supervision and no attempt to attract boys or to make the work pleasant. It is only natural that boys leave their apprenticeship under these conditions.

Again, a number of our foundries are engaged in such spe-

cialized work that no adequate training can be given. Some foundries are engaged on machine work only, others on light floor work only and others again do a purely jobbing business. Naturally, the graduates of an apprentice course in any one of these shops would not be fully qualified foundry mechanics and could not hold positions in any other shops than the one in which they learned their trade or one in which a similar kind of work was done. Accordingly, nothing has been done in the way of apprenticeship in these shops and fairly enough, certainly, because it is unjust to the boy to hold out a promise of complete trade training in a shop which is not qualified to give it.

The complaint is sometimes made also that apprentices are unsteady and that the work done by them costs too much in the way of wages to make apprenticeship possible from the financial standpoint.

However, these difficulties and problems are not insurmountable. All of them have already been overcome more than once. In fact, we have possibilities and favorable features in our foundry industry which should more than compensate for the disadvantages. In the first place, our foundry owners are interested in apprenticeship and that is an excellent beginning. The foundation for a good apprentice system already exists. Apprenticeship can never succeed unless it has the support of the people who have their money invested in the industry. It now remains for the owners to interest the operators of their shops.

Again, the fact that the foundry industry in Oakland is small may be a distinct advantage rather than a disadvantage. In the first place, since only a few boys will have an opportunity to learn the foundry business, it will be possible to select them with much care and to admit to the shops only those boys who are clearly of the very first class. Also, in the small shops individual instruction of each apprentice and personal attention to his problems are not only possible but almost inevitable. The success of apprentice training depends, after all, upon the relation which exists between the apprentice and the foreman and other officials who will teach him his trade and assist him out of difficulties which he may encounter.

The problem of irregularity of attendance on the part of apprentices and the high turnover can probably be overcome by

the institution of formal apprentice courses and programs in our shops. In my opinion, such a program should include a contract which will be signed by the employer and the apprentice and also by his parents, a definite scale of wages covering the entire apprenticeship period to be rigidly adhered to, a considerable bonus for apprentice graduation, to be forfeited by the apprentice who leaves before his contract is completed, a carefully planned schedule of work to provide all around skill in the foundry trade, adequate supervision and instruction and properly related school or theoretical study. Such a program of apprenticeship will give the institution a character which it now lacks and which will interest young men in the foundry industry.

Again, the difficulty of specialized work in the various shops can be overcome as it has been overcome in other localities by means of district organization and co-operation. The foundry which makes machine work only can combine with another foundry which does jobbing work and between the two of them an adequate training program can be worked out. Each foundry would keep the apprentices for a part of the training period. If two foundries cannot furnish full training a third or a fourth might be added to the group and the three or four foundries could be jointly responsible for the training of a certain quota of mechanics. Of course, this would require intelligent team-work between the shops, but the fact that it has already been done in some places proves that this is not impossible.

In addition, a campaign of promotion and education will need to be carried on not only in the industry but in our community, in the schools, among parents, in civic groups, and even among our mechanics. In this way a favorable opinion toward apprenticeship can be created and when once this exists other difficulties and problems will easily be overcome.

Our people are thinking about apprenticeship, the seed has been sown, a beginning has been made. High wages are paid by the foundry industry in our part of the country and there is no reason why young men should not take up foundry work if it is properly presented to them. It is more than possible that another year or two will find a considerable number of young men in training in the foundries of Oakland.

Apprenticeship in the Quad-Cities

By S. M. Brah,* Moline, Ill.

Community apprentice training programs have not yet become so common that a briefly detailed description of this inter-city program will be amiss.

The Quad-Cities or Tri-Cities, as they are sometimes called, are made up the cities of Davenport and Bettendorf, Iowa, Moline, Rock Island and East Moline, Illinois, Bettendorf being the smallest and newest of these communities.

While the political eccentricities prevent a combination of the cities in each separate states, the industrial leaders have not followed in the wake of politics, but have united in practically all their undertakings, this program being no exception.

These cities make up the sixth largest foundry center in the U. S. A. Their combined population is approximately 250,000 inhabitants. The manufacturing is principally metal working, with farm implements and accessories predominating. Machine tools, automobiles, gas engines, gas electric locomotives, and foundry equipment, offer a diversity from the agricultural line.

Among the more active of the inter-city organizations is the Quad-City Foundrymen's Association. This body promoted the apprentice training work as it is practiced today. It may be stated that following the 1924 Milwaukee convention of the A. F. A. some of the leaders in foundry circles started a campaign that has resulted in a going program. Through the same agency personal acquaintanceship sprung up that later proved to be the actuating force to set the machine in motion. Let us hope that this meeting will be the cause of another shop or community following the same example.

The Quad-City Foundrymen's Association secured the aid of H. A. Frommelt, then of the I. C. S., who, together with two

*District Supervisor, Quad-Cities Foundrymen's Association.

assistants, surveyed the community, drafted a plan and set forth the specification for the program.

The shop schedules were patterned after the general idea of a definite amount of time to be spent in each branch of the foundry trade. Cupola, core making, sand mixing and conditioning, bench, floor and machine molding, cleaning and inspection go to make up the general trade training outline. Most of the plants are too small to employ an individual who can spend all of his time teaching apprentices. The foremen are doing this at the present time. While it was a question as to whether the foreman could act in this capacity, it will be sufficient to say that he is called upon to train all newcomers, so why shouldn't he do likewise with the apprentice? This would not be advocated for a large shop having as many as 15 or 20 foundry apprentices.

In addition to the shop training, a class room program offers additional training in related work—mathematics, English and drawing. Special correspondence courses are used.

The following reasons point out the advantages of these courses.

1. A broader training is possible, than through lecture method, except when unlimited amount of money is available.

2. Ability to absorb new apprentices into a class at any time without detriment to himself or others.

3. Encouragement offered dull and brilliant pupils, each progressing at his own speed and not contingent upon the class as a whole.

4. Elimination of details of lesson correction, records of grades, monthly reports.

5. Benefit of newly revised and up-to-date text material at all times.

6. Shop operations, equipment and processes can be handled in the classroom, making it possible for the apprentice to get the *whys* and *wherefores,* as well as the manipulative training which is given in the shop.

The class work is given in the public schools and is handled by teachers in the employ of vocational training departments of local schools.

The interest of the industries has been increasing steadily.

Civic organizations, as well as school people, are showing a marked degree of interest. The supply of applicants far exceeds the opportunities for employment as apprentices.

The turnover has been remarkably low, annually amounting to 19 per cent. This is more or less of a criterion of the correctness of the method involved being satisfactory to employers and employees alike.

A supervisor is employed who is directly responsible for the program as a whole. The duties of the district supervisor are as follows:

The promoting of the idea among industries not yet co-operating, establishing contacts with schools and civic organizations to maintain the interest of the people in the community, maintenance of a control chart which shows the amount of time spent by each apprentice on the various processes, interviewing of applicants and maintaining contacts with parents, developing outside activities for apprentices, acting as general counsel for employer and apprentice alike.

A committee, made up of executives from each community, meets monthly to review past progress and pass upon the policies involved in future plans.

Results

The tabulated results listed will show the true condition of the program, which has just completed its second year.

TURNOVER

	1st Year			2nd Year		
	Machine Shop	Foundry	Pattern Shop	Machine Shop	Foundry	Pattern Shop
Quit	2	9	..	1	7	..
Lack of interest	5	1	..	..	..	..
Lack of ability	3	1	2	..	1	..
Discipline	3	1	1	..	..	..
Transfer	..	..	..	..	..	2

Total turnover, 37—based on percentage of total number apprentices at this time 30%
Average monthly turnover for two years 1.25%

TURNOVER SCHOOL vs. SHOP FATALITY

	1st Year			2nd Year		
	Machine Shop	Foundry	Pattern Shop	Machine Shop	Foundry	Pattern Shop
Inability to master school work	2	1	..	..	1	..
Inability to master shop work	6	2	..	..	..	..

GENERAL SUMMARY

	1st Year	2nd Year
Number of plants employing apprentices	17	21
Minimum number of apprentices in any plant	1	1
Maximum number of apprentices in any plant	12	13

	1st Year	2nd Year
Number of plants with one apprentice	3	2
Number of plants with two apprentices	3	2
Number of plants with three apprentices	2	4
Number of plants with four apprentices	3	4
Number of plants with 5 to 9 apprentices	3	5
Number of plants with 10 to 13 apprentices	3	4
Total number of plants	17	21
Plants dropping out	None	None

APPRENTICES AND APPLICANTS

	End of 1st Year	End of 2nd Year
Number of apprentices at work in all shops	84	125
Number of apprentices attending classes	60	119
Number of apprentices estimated in the survey	125	250

Maximum number of apprentices called for in survey 425

APPLICATIONS ON FILE

	End of 1st Year	2nd Year	Apprentices at Work, 2nd Year
Machinist	50	125	55
Foundry	48	60	28
Pattern shop	8	24	21
Electrical	5	30	3
Plumbing and pipe fitting	4	8	1
Drafting	8	23	..
Sheet metal	2	1	2
Painting	1	9	..
Office	2	6	4
Manufacturing	1	3	5
Wood working	2	20	..
Unclassified	14	11	6
	145	320	125

Applicants on hand classified as to educational qualifications:

Number completed grade school	83
Number completed 1st year high school	80
Number completed 2nd year high school	37
Number completed 3rd year high school	13
Number completed high school	107*
Total	320

Note: No applicants accepted unless they have completed eight grade.

*Many applicants have filed names but are not available as they have gone to college, or accepted some other position.

COST

The cost of training in the shop is a questionable item. During the first year the apprentice may be considered a liability but the following years he should prove an asset and will under the proper guidance and supervision.

COST OF TRAINING APPRENTICES PER YEAR (TO PLANT)

Instruction, material and equipment	$12.50 per apprentice
Class time	57.60 per apprentice
Supervision cost	None*
	$70.10

*Foreman acts as instructor. Inasmuch as he trains other men his time should not be counted.

COST OF TRAINING TO COMMUNITY

Salary of supervisor, class instructors, incidentals $5,000.00

$$\frac{\text{TOTAL COST} \ldots\ldots \$5{,}000.00}{\text{Apprentices} \ldots\ldots 125} = \$40.00 \text{ per apprentice per year.}$$

Many companies have been waiting for a community program to organize before attempting anything in their own shop. I feel that this is a mistake. I say this having in mind several communities which planned apprentice training programs during the last three years but never carried out their plans. One case worthy of mention where an enterprising concern waited upon the community program for two years and then started its own program. At the same time this company instituted a bonus plan, group insurance, and medical service as well, proving that now is the time, regardless of what other activities are under way.

Harvey Community Apprenticeship

By W. B. Keast*, Harvey, Illinois

Harvey is a typical manufacturng city of approximately 18,000 inhabitants. The products of its manufacturing plants are many and varied. There are sixteen plants in Harvey which employ from 100 to 1,500 men. In these manufacturing companies there are represented about 30 trades and it will be noted that the shops here represent the typical job shops as well as production shop.

There has been apparent, in the past, a lack of skilled and trained workers in the various trades. Because of the deficiencies in numbers of these responsible men, who have had training and who possess the ability to accept responsibility, Harvey presents the ideal situation for the need for training of apprentices in a systematic way. Therefore, active interest has come about on the part of the manufacturers towards the training of apprentices

*District Apprentice Supervisor.

and the Thornton Township High School is interested for the reason that it can definitely meet a community need by its interest in apprenticeship. The school serves a two-fold purpose in the program. First, through the process of natural selection and elimination, it serves the purpose of placing the proper individual in a definite apprenticeship. This, of course, is determined by the individual's interest and aptitude in the work he does throughout his high school course. Second, it is the work of the school to give the apprentice throughout his period of training, school work which is directly related to his shop.

The plan now in operation is as follows:

Each plant has some of the apprentices indentured to it. The apprentice will receive the same training in a given trade regardless of the manufacturing plant to which he is indentured.

All forms used, such as indenture forms, report cards, control charts, etc., are uniform throughout the plants.

The apprentices in the various plants all receive equal compensation during the apprenticeship in all plants.

Each apprentice throughout his period of training attends related class room instruction in Thornton Township High School for eight hours each week. The apprentice receives full time for the eight hours spent in school provided his school work is reported as satisfactory.

The Vocational Director of Thornton Township High School acts as district supervisor of apprentices and is a coordinator between the school and the various plants.

Three classes of apprentices are provided for:

1. An apprenticeship of four years is laid out for the individual who has completed the eighth grade work.

2. An apprenticeship of three years for a boy who has graduated from high school.

3. A special apprenticeship designated as a post-graduate course. This course is a two-year course and usually includes work in all departments of the plants. It is given to young men who have graduated from an apprenticeship in some particular trade or to college trained men. It is given for the purpose of training sales engineers or for the purpose of training for department heads.

At the present time there are five (5) plants in the community affiliated with the Harvey Apprenticeship and we are expecting more to join after the "try out" period.

The number of apprentices total 68. They are divided among the different trades as follows:

Foundrymen	16
Pattern Makers	14
Machinists	6
Tool Makers	5
Die Makers	3
Electricians	6
Structural	2
Assembly	3
Engineers	6
Draftsmen	4
Miscellaneous	3

The maximum number of plants in the Harvey District will be twelve. Many of these are small and will employ very few apprentices. We hope to have them all represented sometime so as to have a 100 per cent Community program.

The maximum number of apprentices will be somewhere around 160.

The approximate maximum of Foundry apprentices is 35.

An apprentice bowling league has been organized and has been running for two months. Our apprentice basket-ball team has completed a very successful season.

Risers, Their Need and Feed

By R. R. Clarke,* Erie, Pa.

In the main, risers connect with castings for one or more of four distinct purposes.

1. To relieve strain of hard pouring,
2. To circulate metal through the mold,
3. To entrap and hold dross from the casting, and
4. To feed the casting against shrinkage.

Of these four functions this paper is concerned with the last named only, and will deal with it exclusively.

The feeding riser is a molding tribute to shrinkage or contraction. This contraction is a decrease in the volume of a metal body, mass remaining the same. It is a decreed and unescapable exaction and is common to all metals and alloys though not to the same degree in each. There is no absolutely non-shrinkable metal.

The need of a feeding riser is the outgrowth of a casting condition or set of conditions from which shrinkage derives an abnormal advantage. Among these conditions the following are primarily outstanding:

1. Where the metal is by nature heavy in shrinkage: As noted, all metals shrink but not all to the same degree. Copper 80, tin 10, lead 10, for instance, has far less shrinkage than copper 60, zinc 40. In different forms and volumes the latter will demand copious feeding, where the former may require none. Of those metals of high inherent shrinkage, pure copper is a common example. Among other metals and alloys, aluminum, aluminum

*Alloy Foundry, General Electric Co.

base alloys, nickel silver, monel metal, "copper-aluminum alloys," and copper-high zinc alloys, are well known for their shrinking treachery and always are subjects of riser consideration. In the alloys containing lead as well as those where the zinc content is less prominent, the shrinkage reduces correspondingly and the riser situation becomes less critical. In illustration of high shrinking alloys we note manganese bronze, yellow brass aluminum bronze, and nickel silver. Of those with less shrinkage we observe red brass (85-5-5-5), phosphor bronze (80-10-10), gun metal (88-10-2) and bell metal (copper 83⅓, tin 16⅔).

2. Where the metal exaggerates its average natural shrinkage by virtue of its quality or condition: This will occur often in poor grades of metal, especially in the base metal of an alloy, as in low quality aluminum in the aluminum base alloys and low grade copper in the copper base alloy. The "rawness" of an alloy derived from a high percentage of virgin metal used along with a low percentage of re-melt metal is a further potent factor. All other factors being equal a heat of all new metal will far outshrink the same heat poured into a casting on second or third melting.

3. Where the metal or alloy in its semi-fluid and plastic states is low in physical properties such as tensile, cohesion, etc.: Between a light and heavy section adjoining each other, a severe rupture or cleavage will occur by the "setting" strain in one metal or alloy and not in another. A fairly high zinc, copper-base alloy with no lead compared to the same alloy with a fair addition of lead will serve to illustrate. In the one instance rupture will materialize; in the other it will not. The power of the lead to reduce the *quantity* of shrinkage is no doubt in part responsible. At the same time the author's conviction is that a raising of physical properties of the plastic mass by the lead is not without its just claims for credit.

4. Where, because of conflicting conditions the metal has to be poured above or below that temperature at which its shrinkage is least expressive: When poured cold, aluminum and its alloys shrink least. An aluminum casting containing heavy and light sections must be poured hot to run the light section which may necessitate a riser on the heavier section to overcome the greater shrinkage of the hotter pouring. Gun metal, on the other hand, expresses less shrinkage when poured hot than when poured cold. When it is desired to relieve some part of the mold of

severe sand burning and the metal in bulk must be poured cold, a riser is often essential to control the greater shrinkage expressing.

5. *Where the casting expresses metal bulk:* This condition sets up where the ratio of volume to surface is high. If we take a circular disc eight inches diameter by one inch thick, a single medium sized pouring gate will hold it against localizing shrinkage which it usually expresses in cope depression. The volume of this disc is practically 50 cubic inches. Its surface is 125 square inches. The ratio of volume to surface is as two to five and it cannot be said to be bulky. By increasing the thickness to two inches the volume increases to 100 cubic inches, the surface to 150 square inches and the ratio becomes as two to three. As the casting increases in bulk the cope surface will indicate a tendency to sink when poured with the same gate. Now if the thickness of the disc increases to 12 inches, the volume becomes 600 cubic inches, the surface 400 square inches, and the ratio of volume to surface as three to two. In other words, the casting's volume is one and one half times its surface. Here bulk is decisive and a full, solid casting throughout requires a feeding riser regardless of the metal or alloy used. Now, if we increase the two-inch thick disc to a diameter of 24 inches, then the volume becomes 904 cubic inches, the surface 980 square inches and the ratio almost one to one. Here bulk is moderately high and the distance from any one circumference pouring gate, regardless of its size, to the center of the disc on to the extreme opposite point from this pouring gate is too great to be completely dominated by the gate feed. A casting of this size and shape will therefore give better promise if several feeding risers be placed equidistant on the circumference of the disc. A riser in the center of the disc is another possibility. This center riser, however, must be necessarily heavier than circumference risers in multiple and makes for a harder condition of removing the riser from the casting. Incidentally all figures increasing in dimensions advance in bulkiness. In a two inch cube volume to surface is as 1 to 3; in a four inch cube as 2 to 3; in a six inch as 1 to 1; in a 12 inch as 2 to 1.

6. *Where the pouring gate is either impossible of placing at some required feeding point or functions better in the running of the casting at some other point than this required feeding point:* The eight-inch diameter disc one inch thick will serve to illustrate.

Suppose this disc to have a three-inch diameter with a three-inch high solid hub in its center. The casting could be run either from the circumference or from the hub by a subterranean gate but in neither case could it be always depended upon to control shrinkage in the hub. A feeding riser on the hub would be more assuring. Deep mold castings of bulk run from the bottom are further examples.

7. *Where the solidity of casting metal is of prime importance:* This occurs, for instance, in pressure castings. A bushing, 6 inches diameter by 10 inches long, with a two-inch core will illustrate. If the bushing, of some low shrinking alloy, be intended only to be cut into washers, the casting might get by without feed, but if meant for a high pressure cylinder liner, a feeding riser on the casting functions to give the greater required density of the metal.

8. *Where variables of bulk adjoin each other in the casting:* If a rather light, thin section join a fairly heavy bulky section in a casting, the light thin section will solidify and exact its toll from the heavy section while this heavy section is yet fluid and in full possession of its liquid properties. Cleavage or rupture between the two sections is therefore a remote possibility because the fluid metal of the hub adjusts the loss at the overall expense of the hub. But if the two sections be nearly equal in bulk and freezing rate, then the pull of the one is exerted on the other in its viscous or plastic metal state and the toll taken cannot be so adjusted. It is then cleavage or rupture between the two sections occurs. In all such cases of bulk variables the feeding riser furnishes a promising solution. The metal chill is another remedy frequently used in such cases. The chill, however, is not a part of this discussion and will not be further considered in it.

9. *Where bulk of prominence is high in the cope of the mold:* If we feed a casting section, from a feeding supply beneath that section, we have gravity against us. If the same section be fed, from a supply above, downward, gravity aids the process. Whereever bulk of prominence occurs above the point of gate supply, the feeding riser becomes a subject of consideration. Any casting section, it might be noted, can be fed upwards from a metal supply beneath it but not with the same sized gates and gate pressure nor to the same advantage as feeding from above it.

10. Where, at the immediate finish of pouring, metal temperatures vary illogically in different zones of the mold: These variations occur mainly from delivering conditions in point of time and distance and have a decided effect on localizing shrinkage. A solid disc with a moderate central hub on the under side will illustrate. If we gate on the rim the metal crosses to the hub, fills it and cools while the disc of the mold fills. The hub metal is therefore colder at pouring finish than the plate metal, which is a logical order and will obviate a riser under moderate conditions of hub bulk. Now if we gate with a horn gate on the hub from in under then the opposite of conditions attend the relative temperatures. Such conditions in an alloy of hot metal shrinkage may require a riser to overcome that shrinkage. Many occasions arise in molding where similar conditions of relative temperatures make for or against the riser need.

11. Where the need of feed lies beyond the pouring gate control. Often the best pouring point of a casting is not the best feeding point. Frequently also a running gate cannot be sized to meet feeding requirements. An example occurs in a chunky casting at the opposite end of a long runner gate from the pouring sprue. Here a feed sprue is necessary to hold up the chunky casting.

12. Where metal occurs over a dry core at a point where the core is inclined to cause kick-back disturbance. A riser at such a point lends its weight to live immediate pressure to quell the disturbance and feeds back into vacancies caused by that disturbance after the core has terminated its activities. Many times we have found that a riser at a certain point would dominate a core kick and its consequences, which frequently materializes when the riser is omitted.

13. Where a gate joins a casting: Unluckily, in many alloys of high shrinkage as in copper, high zinc-copper, etc., where a gate joins a casting, a bad gate pin hole will often develop. A riser or bob set over the gate close to this juncture point will supply and deliver a feeding quota of metal and obviate the pin hole.

Four Requirements of a Feeding Riser

The foregoing comprise the main necessities of the feeding riser and will be found to cover the majority of conditions express-

ing in one form or another. With its necessity understood the constructive principles of the riser will now be considered.

That any feeding riser may completely satisfy the demands of its dependent casting, four distinct requirements must be understood and served.

1st—The riser attaching surface must fully cover the zone of final concretion or solidification beyond or beneath it in the casting.

2nd—The riser volume must be ample for the shrinking loss.

3rd—The riser metal fluidity must be maintained to penetrate to the last the shrinking vacancy.

4th—The riser height must be sufficient for a pressure to force the feeding supply solidly into this vacancy.

Briefly, risers should be high, heavy and hot and in direct and unbroken communication with the final shrinking loss. They should further be placed as close to this freezing zone, which is usually the center of mass, in the casting, as conditions will permit.

Constructing a Feeding Riser

In constructing a feeding riser the first consideration is to place it at the point of greatest advantage and to make the size of its attaching surface cover fully the zone of final loss. Every casting or casting section solidifies from all bounding surfaces inward to its center of mass and draws on the immediate liquid metal of the casting to feed the inmoving freezing mass. In a sense the casting feeds itself automatically up to a certain depth of freezing metal but cannot so feed itself to its freezing heart. To safely overstretch this final freezing zone is to correctly determine the area of the casting surface covered by the attaching riser.

The next step is to get a heavy supply of metal above this attaching surface, a supply that will keep its fluidity and continue feeding to the final freezing of the mass center beneath or beyond it. To this end the riser neck must be not too long, never more than from ½ inch to 2 inches and should enlarge at once therefrom into a reservoir form that holds a volume of metal immediately above it, this form increasing in dimensions upwards to its top. In this connection the bottleneck riser as shown in Fig. 1 is the most efficient form of riser of which we know. Regarding the general form of riser, it might be remembered that the round form is the most bulky of all other practical forms and contains

greater volume per surface than any other practical form. It is therefore a better feeder than the cubical, the hexagonal, and all other forms except the spherical, which is, of course, physically impossible in the open-top riser. A feeder attaching to the side of a casting should observe the same general principles as a top attaching riser. These principles are illustrated in Fig. 2. Bad forms of risers are noted in Figs. 3, 4, 5, 6, and 7.

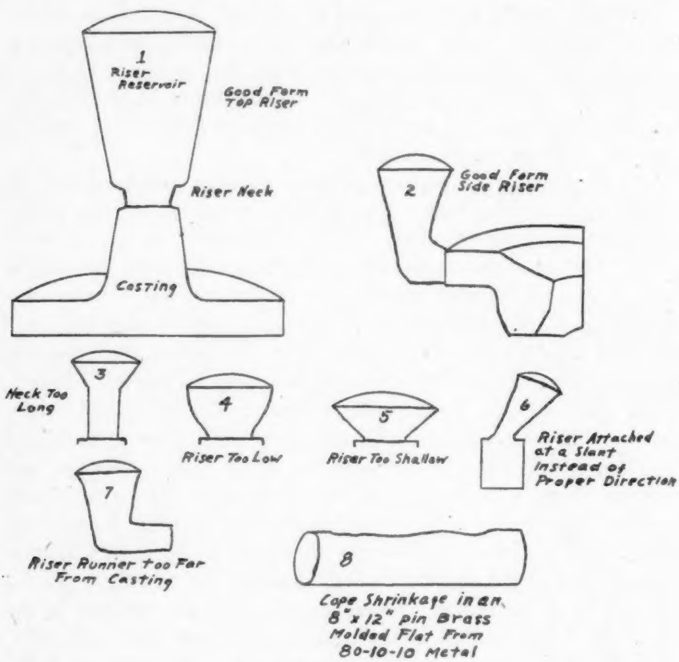
Discussion

Metal flowing from the mold into a riser is essentially colder in the riser than in the casting and will naturally freeze quicker bulk for bulk, which is the improper order for feeding. To attain the correct condition, riser bulk and volume should be predominating and temperature of metal raised by pouring hot metal directly into the riser wherever possible.

The power of a high-up pouring sprue or pressure gate to displace a riser on a bulky, low-shrinking metal casting was a disputed point at the Chicago (1927) convention of this association. The case discussed was an eight-inch diameter by twelve inch long solid cylinder molded on end, gated at the bottom with a small gate and poured of 80-10-10 metal, with no riser attached. At that time the author of this paper questioned the complete solidly and calculated dimensions of a casting so poured. Examining the condition we find the volume to be 600 cubic inches, surface 400 square inches, ratio of volume to surface three to two and the weight close to 200 pounds. Here bulk is decisive and volume heavy. Molded on the flat, this casting shrunk as shown in Fig. 8, showing that heavy shrinkage is an inherent part of the metal in this form, i. e., *that the shrinkage is there.* To assume that the shrinkage suspends merely because the casting is poured on end is an absurdity. Moreover, of two such castings in the same mold and poured at the same instant from the same ladle, the one with a riser weighed two pounds more than the one without a riser. In a series of experiments so made the fed casting invariably outweighed the unfed by from two to three pounds.

Regarding the high gate pressure deriving from a high-up pouring head, it might be stated that this high gate pressure will invariably give a more full and solid casting up to certain limitations than a gate of lower pressure, but the fact cannot be overlooked that this pressure is fundamentally only a hydro-static pres-

sure obeying the laws of a liquid and applying only during the tenure of fluidity in the gate. Once the gate at any point freezes back of the casting, pressure and feeding from the gate at once and alike stop in the casting. To pour from the bottom a heavy casting of this nature with a small runner gate means that when this gate freezes it severs all relations with the casting and leaves the casting, so far as the gate is concerned, absolutely self-supporting against shrinkage regardless of the gate height or pressure.



EXAMPLES OF RISERS

Nothing in molding is more foolish than a heavy bulk or high pressure of metal intended to feed a casting, and connecting to that casting by a channel that freezes tight long before the casting itself departs its liquid or plastic state.

Effect of Melting and Pouring Conditions Upon the Quality of No. 12 Aluminum Alloy Sand Castings

By T. W. Bossert,* New Kensington, Pa.

It is a foundry maxim that metal should be poured at the lowest temperature possible for running a particular casting, and that, subject to practical limitations, the temperature of the metal during the melting should not be permitted to rise above the pouring temperature. The value of the above rules has been proved time and again in aluminum founding, yet today too many foundries pay little attention to the matter of temperature control and thus neglect one of the keys of successful, continuous, operation.

The effect of pouring temperature upon the mechanical properties of sand cast aluminum alloys has been studied by many investigators,[1] and references in the literature may be found which recognize that desirable mechanical properties are linked with fine or "close" grain structure in the casting. The presence of a coarse structure and the presence of such defects as draws are always objectionable, yet little exact information is at hand regarding their relation to melting and pouring conditions, as well as upon the relationship existing between crystal structure and the drawing tendency.

*Technical Direction Bureau, Aluminum Company of America.

[1] Gillett, H. W., *Influence of Pouring Temperatures on Aluminum Alloys*, Eighth International Congress of Applied Chemistry, Vol. 2, 1912, pp. 105-112.

The importance of the above factors, namely, melting and pouring conditions, especially in the case of No. 12 alloy (the commercial 8 per cent copper aluminum casting alloy) has been recognized for some time, and active steps have been taken in the laboratories of the Aluminum Company of America to obtain more exact information regarding their effect upon the quality of No. 12 alloy castings.

Consideration of the conditions ordinarily met with in the foundry indicated that the following factors should be studied:

1. Melting Temperature
2. Pouring Temperature
3. Soaking Time in Furnace
4. History of Material prior to final remelting.

It has been shown, that, while drawing can to a large extent be minimized by changes in molding method, yet the drawing tendency increases with the coarseness of the crystal structure in the casting. Whenever a coarse crystal structure is produced in a casting, the tendency for drawing is invariably stronger than is the case when the crystal size is fine. Factors causing a coarse structure, and therefore the tendency for drawing, are excessive melting or pouring temperatures, and soaking of the metal in the molten condition. These same factors, furthermore, tend to increase the tendency of the casting to crack. It has also been found that these effects due to improper temperature conditions can be eliminated by a subsequent remelting.

The general rules regarding melting and pouring temperatures have therefore been found to hold, and the results have further emphasized the necessity for accurate temperature control, both at the furnace and at the mold.

Experimental

Materials Used: The No. 12 alloy used was of two kinds, namely:

1. Commercial No. 12 alloy ingot.

2. No. 12 alloy made from commercially pure aluminum (99.2 per cent) and 50-50 per cent aluminum copper alloy, the metal being cast into sand molds without intermediate pigging and remelting. In the cases where high silicon or iron contents were

desired 15 per cent silicon and 5 per cent iron hardeners were employed.

Preparation of Alloys: The metal was melted in plumbago crucibles, and the melting operation carried out in an electric resistance furnace equipped with automatic temperature control. Accurate check of the metal temperature in the furnace was obtained by means of an iron constantan thermocouple immersed in the bath, and the temperature of the metal immediately before pouring was determined by means of a quick reading, open end chromel-alumel thermocouple, such as that described by Marsh.[2]

Manner of Testing: The plan of this work required tests for two effects, namely: draws and crystal size.

In order to avoid confusion, a definition of a "draw," as differentiated from a "shrink," is necessary. A "shrink" is generally a smooth depression on the surface of a casting due to unequal cooling or to insufficient feeding during solidification. A "draw," on the other hand, is that defect, occurring generally in the corner of a casting, or in a relatively thick section adjacent to thinner sections, which appears as worm-like channels on the surface of the casting. These channels may be quite deep, so that the uneven surface produced cannot be removed by the ordinary amount of grinding and polishing. It is thought that the draws are produced during solidification by normal segregation occurring in alloys, coupled with insufficient feeding to the heavy section, by the adjacent light sections. The low melting constituent (consisting of an alloy approximately the eutectic composition—33 per cent copper—in No. 12 alloy) is drawn from the surface of the casting to the interior, thus leaving series of fine channels around the crystals formed early in the process of solidification. Thus draws can be produced by any alloy which freezes over a range of temperature, and which shrinks upon solidifying.

In order to fulfill the purpose intended in this work, it was necessary to obtain a pattern for a sand casting containing sections prone to develop draws but such that a perfect casting could be poured under correct conditions of metal treatment. A simple fry pan pattern was found which produced a perfect casting under such correct conditions, and which produced castings containing

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[2] Marsh, K., *Temperature Control in Aluminum Foundries*, The Foundry, vol. 55, March 1 1927; vol. 55, March 15, 1927.

draws under other conditions. In all cases the arrangement of gates, moisture of sand, and all variables relating to the molding were maintained as nearly constant as possible. Thus the only variables existing were those imposed on the metal before it was poured into the mold.

The same casting used for the detection of draws was also used to study crystal size, thus making it possible to determine the relationship existing between draws and crystal size. Crystal size was determined by etching the surface of the casting with a suitable reagent to develop the structure.

I. Effect of Melting Temperature

In this phase of the work melting temperatures ranging from 1320 to 1700 degrees Fahr. were employed. It was found by trial that 1320 degrees Fahr. was the lowest pouring temperature at which the metal completely filled the mold, with the arrangement of gates used.

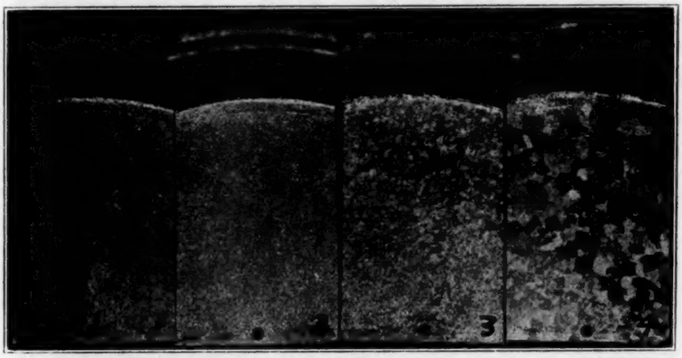
In order that all other variables concerned with the treatment of the metal might be maintained constant, all specimen castings were poured from the same original melt. During the heating of the melt to the maximum temperature, 1700 degrees Fahr., metal was removed at the desired temperatures up to 1700 degrees Fahr., and poured when it had cooled to 1320 degrees Fahr. This pouring temperature was maintained constant throughout this series.

The results of this series are clearly illustrated in Fig. 1. The sections shown were cut from identical positions, relative to the one pouring gate, in the pans, so that they represent sections subjected to identical chilling and feeding conditions.

The detrimental effects of increasing the melting temperature are apparent in this illustration. It was found rather difficult to faithfully reproduce draws in these illustrations, but careful examination of the areas at the junction of wall and bottom will not fail to reveal this defect.

As shown in Fig. 1, and also evidenced by other specimens not illustrated here, increase of melting temperature above 1400 degrees Fahr. has resulted in a definite regular increase of crystal size. The same effect was found as regards draws, that is, increase of melting temperature caused an increase in depth and number of draws, as well as in the area over which the draws extended.

Crystal size at 1320 degrees Fahr. and 1400 degrees Fahr. was fine and eutectic draws were absent. These temperatures, therefore, can be regarded as safe temperatures to which to melt the metal. Temperatures higher than 1400 degrees Fahr. need not be used for pouring the casting under consideration, and therefore should under no circumstances be sanctioned. In certain cases might seem impossible to operate successfully when melting temperatures below 1400 degrees Fahr. are observed. In the majority of cases, however, pouring temperatures can be materially reduced by changing the gate so as to allow the metal to



1320° F. 1400° F. 1500° F. 1700° F.

FIG. 1—EFFECT OF MELTING TEMPERATURE. SPECIMENS MELTED TO INDICATED TEMPERATURES AND POURED AT 1320 DEGREES FAHR.

enter the pattern cavity at a number of points. Otherwise a slightly less desirable crystal structure and danger of drawing in the casting must be accepted as a result of increasing the melting temperature to the required value.

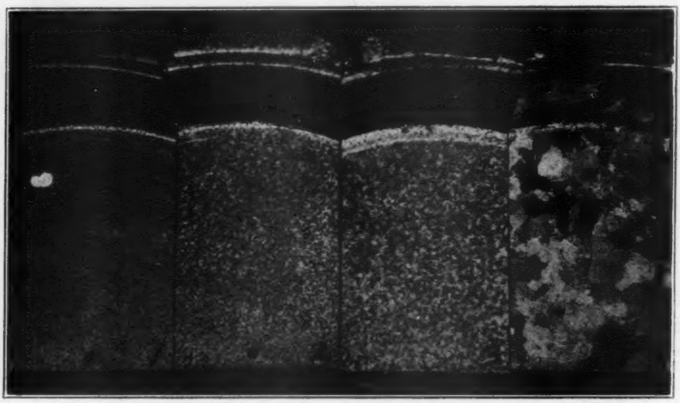
The important point to bear in mind regarding the effect of melting temperature is that once metal has been heated above the required temperature it has suffered certain detrimental effects which are apparent in the casting. Simply cooling the metal down to the correct temperature does not correct the damage done.

II. *Effect of Pouring Temperature*

The results just given would lead one to suspect that increase of pouring temperature, which automatically carries with it an

equal increase in melting temperature, would have a harmful effect upon the metal equal at least to that caused by raising the melting temperature. Whether there is a further effect due to higher pouring emperatures, i. e., due to not cooling the metal to the proper temperature, was ascertained by the following experiments:

Test castings were poured at temperatures from 1320 degrees Fahr. to 1700 degrees Fahr., the metal for all castings being taken from the same melt, and the melting temperature for each successive condition being at no time more than 10 degrees Fahr.



1320° F. 1400° F. 1500° F. 1700° F.

FIG. 2—EFFECT OF POURING TEMPERATURE—MELTED TO AND POURED AT INDICATED TEMPERATURES

above the pouring temperature. The test was carried out by heating the metal to 1320 to 1330 degrees Fahr., pouring suitable castings at 1320 degrees Fahr., then raising the temperature to 1400-1410 degrees Fahr., pouring castings at 1400 degrees Fahr., and so on to 1700 degrees Fahr.

The results of this test are summarized by the sections of castings shown in Fig. 2. It will be noted that there is a pronounced coarsening of grain with increase of pouring temperature, that drawing appears in the casting poured at 1400 degrees Fahr. and rapidly becomes more pronounced as the pouring temperature is increased.

A comparison between results obtained in the two series of

tests, represented by Figs. 1 and 2, immediately points out that further detrimental effects in addition to those caused by high melting temperatures, are caused by high pouring temperature. *For a given melting temperature,* above 1320 degrees Fahr., the grain size is definitely coarser and eutectic drawing more pronounced, in metal poured at that temperature than in metal cooled to the proper pouring temperature. It is important to note that eutectic draws appear plainly in the specimen casting poured at 1400 degrees Fahr.

Control of pouring temperature has been shown to be quite as important as control of melting temperature. In the first place, a high pouring temperature is evidence of a high melting temperature, the evils of which have been discussed. Then, the high pouring temperature in itself tends to increase the formation of draws and a coarse structure, so that the effect of a high pouring temperature is markedly more harmful than that of a high melting temperature alone.

III. Effect of Soaking

On a number of occasions inconsistent results were obtained on metal which had been allowed to remain in the furnace for some time in the molten condition. The inconsistencies generally occurred when higher temperatures were being employed, indicating that possibly soaking at high temperatures had an effect upon the metal not produced by soaking at normal temperatures.

The above indication was proven the correct one in the following manner.

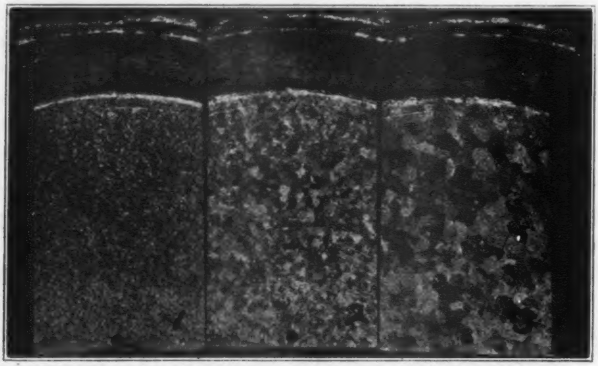
Two series of soaking tests were carried out by melting sufficient No. 12 alloy for pouring three sets of castings. The first set was poured as soon as the metal temperature had reached the desired temperature, the second set was poured at the soaking temperature after a 4 hour soak, and the third set was poured after a 24 hour soak.

The first series was soaked and poured at 1320 degrees Fahr., the second series at 1450 degrees Fahr.

Close examination of all castings made from metal soaked at 1320 degrees Fahr. revealed no differences in crystal structure. No draws were detected in any castings. The sections illustrated

(1) 0 Hours (2) 4 Hours (3) 24 Hours

FIG. 3—EFFECT OF SOAKING AT 1320 DEGREES FAHR.—SOAKED FOR TIMES INDICATED AND POURED AT 1320 DEGREES FAHR.



(1) 0 Hours (2) 4 Hours (3) 24 Hours

FIG. 4—EFFECT OF SOAKING AT 1450 DEGREES FAHR.—SOAKED FOR TIMES INDICATED AND POURED AT 1450 DEGREES FAHR.

in Fig. 3 represent metal soaked 0, 4 and 24 hours at 1320 degrees Fahr. They give no indication that soaking has been detrimental.

If Fig. 4 is examined, however, a sharp increase in grain size and in eutectic drawing will be noted as the soaking time is increased. The metal shown in Fig. 4 was soaked at 1450 degrees Fahr.

With the above evidence at hand the cause of inconsistent results sometimes encountered when working at the higher temperatures was plain, especially since the increase in grain size after 4 hours' soaking was as pronounced as indicated.

The fact that soaking at elevated temperatures produced detrimental effects in a relatively short time while a low temperature soak of 24 hours' duration produced no such effects again argues for low melting temperatures. As a general rule, soaking metal for long periods of time is not to be recommended, but when this procedure cannot be avoided it is most important that the metal temperature be kept as low as practicable lest harmful effects result.

Effect of Previous History of Metal

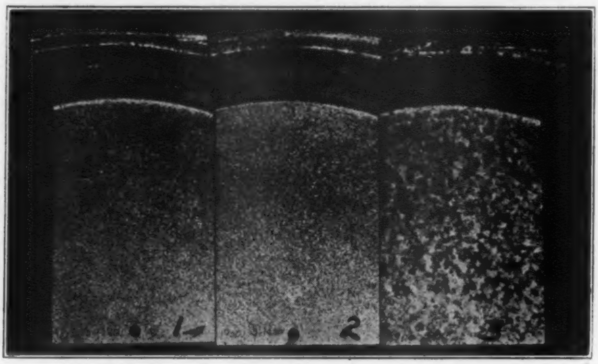
The question naturally arises whether and how metal which has been damaged by any of the treatments described above can be corrected. The detrimental effects of high temperature and soaking treatments have been demonstrated, so that these methods cannot be used to correct effects caused by them.

It has been found that complete correction of the effects described in this paper can be brought about by casting the damaged metal and remelting. Metal which has been remelted to 1700 degrees Fahr., and poured at 1700 degrees Fahr., which procedure is one of the most damaging conditions that can be imposed on it, can be made normal by again remelting. This is shown in Fig. 5, which reproduces sections of pans poured at 1320, 1400, and 1500 degrees after the metal had been cast at 1700 degrees and remelted. Comparison with Fig. 2 will show the structures quite similar.

In the second remelting control of melting and pouring temperatures must not be neglected. If the metal is again remelted and poured under improper conditions the metal will again be

damaged, in other words, remelting is effective in removing the detrimental effects of the preceding melting, et cetera, but does not guarantee against damage if the metal is again improperly handled.

A discussion of the effect of previous history of the metal upon the quality of the casting also raises the question whether the quality of the product produced from the commercial No. 12 alloy ingot differs from that produced by direct alloying of the



(1) 1320° F. (3) 1500° F. (2) 1400° F.

FIG. 5—EFFECT OF REMELTING OVERHEATED METAL—REMELTED FROM METAL ORIGINALLY POURED AT 1700 DEGREES FAHR., THEN CAST AT INDICATED TEMPERATURES

constituents of the material without interposition of the pigging and remelting operations. Providing the melting and pouring conditions previously discussed are met, no difference in quality of castings made by the two methods under consideration will be found.

Relationship Between Crystal Structure and Drawing and Cracking Tendencies

Throughout this discussion the simultaneous occurrence of coarse crystal structure and drawing, both of which are objectionable, has been pointed out. It has been clearly shown that a coarse structure results from high temperature melting and pouring, and

high temperature soaking of the molten metal. Drawing in a casting can be minimized by changes of gating, but the tendency for drawing is invariably present in a casting whose structure is coarse, and which has, therefore, been treated in one of the ways previously described as causing such a structure. It has also been found that the tendency of castings to crack increases under the same conditions as produce a coarse structure and drawing. This point is very important, as oftentimes cracking can be prevented by observing proper melting and pouring conditions.

General Applicability of Conclusions

The general effects described in this paper are applicable to all No. 12 alloy castings. The actual temperatures below which satisfactory castings are produced, and above which unsatisfactory castings result, apply only to the test casting used in this work. The temperature range within which satisfactory results are obtained depends to a large extent on the casting, and will be wide, in some cases, so that satisfactory castings can be poured at temperatures appreciably above 1400 degrees Fahr., while in other cases the range will be very narrow.

The general effects of temperature and time, as reflected in the quality of the resultant casting, are not altered by variations in iron or silicon content from 0.5 to 1.5 per cent. Variations of these constituents in No. 12 alloy are effective in altering to a slight extent the degree of drawing and the absolute crystal size, but they have not been found to change the general effects due to temperature and time described here.

The normal variations which occur from lot to lot of the same metal may also alter somewhat the degree of drawing and absolute crystal size, but the general effects due to temperature and time are not altered by these variations.

Thus the effects of melting and pouring conditions are not influenced by the casting to be made, the impurity content of the alloy, a particular lot of metal, or the previous history of the metal.

General Conclusions

The following facts have been established as a result of the work described in this paper.

1. There appears to be a definite relationship between crystal size and drawing, in that a coarsening of crystal structure indicates increasing tendency for draws to appear.

2. With constant pouring temperature, increase of melting temperature produces increase of crystal size and causes drawing.

3. An increase in pouring temperature results in more pronounced drawing and coarser crystal structure than does an identical increase of melting temperature alone.

4. Soaking tends to cause formation of draws and coarse crystal structure. This tendency is much more pronounced at high than at low soaking temperatures.

5. The same conditions which cause coarse crystal structure and drawing also tend to promote cracking of the casting.

6. Remelting has been found to remove the detrimental effects, as regards drawing, cracking, and coarse structure, produced by the previous melting.

7. The basic effects described are not altered by change of pattern, variations in impurity content, or normal variations encountered from lot to lot of metal, and can be produced on metal remelted once or remelted any number of times.

Summary

The above conclusions emphasize the necessity for accurate control in No. 12 alloy melting. They show that satisfactory castings can be made, under proper temperature and time conditions, from a pattern which under different conditions would produce unsatisfactory results. Temperature of metal must be controlled at both furnace and mold, and equipment must therefore be arranged so that there is a minimum drop of metal temperature from furnace to mold. Soaking of the metal should be avoided, but if it cannot be eliminated, should be carried out at temperatures as low as possible.

At the present time no logical explanation for the phenomena which have been discussed has been found. Investigational work is being continued on this particular subject and it is hoped that a satisfactory explanation of the interesting effects disclosed may be brought to light.

Refractories for Brass Foundry Furnaces

By H. M. St. John,* Detroit, Mich.

Abstract

This paper supplements a previous report by the Committee on Non-Ferrous Survey, a sub-committee of the Joint Committee on Foundry Refractories. It classifies the various types of brass-foundry furnaces and discusses refractory experiences with each. An attempt is made to indicate the relative importance of refractory requirements in different furnaces and to show the progress which is being made in meeting these requirements. Emphasis is placed on the desirability of improving "average results" to a point where they more nearly approach "best practice."

Introduction

At the Detroit meeting of the American Foundrymen's Association in September, 1926, the Joint Committee on Foundry Refractories presented a report by the Sub-Committee on Non-Ferrous Survey. The present paper includes the information given in that report but also includes additional data and conclusions based on these data which represent the personal opinion of the author rather than an official expression by the committee.

In planning its work it was the purpose of the committee to accomplish three objects.

1. To learn what is the average experience of brass foundrymen in their use of refractories and what are the most serious difficulties encountered.

2. To disseminate this information among foundrymen in such a way as to permit each to grade his own practice and, by

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utilizing the experience of others, obtain in his own foundry results equivalent to what may be termed "best practice."

3. To learn whether it is practicable to simplify brass foundry refractory shapes by adopting standards which would decrease the number of sizes and shapes employed.

To these ends a questionnaire was mailed to 225 representative brass foundries. From these some ninety useful replies were ultimately received, most of which were available in time for the report previously referred to. The report served to accomplish partially the first two objects above mentioned. The returns from the questionnaire also convinced the committee that, at the present time, any useful simplification of shapes is out of the question because of the many different types and sizes of furnaces in common use. Since that time there have been new developments in the manufacture of refractories and much additional information has been gathered from a few foundries which are actively experimenting in an effort to improve their own refractory conditions. Many of the tentative conclusions which can be drawn from this work are controversial in their nature and, for that reason, are more suitably included in a paper of this character than in a more formal committee report.

The nature of refractory problems depends, first of all, upon the types of furnaces and fuels used. It appears that the following list covers the varieties which are sufficiently important to merit serious consideration.

1. Crucible pit furnaces using coke or hard coal.
2. Crucible furnaces using oil or gas.
3. Open-flame furnaces using oil or gas.
4. Indirect-arc electric furnaces.
5. Induction electric furnaces.

At the time of the survey made by the committee these furnace types had the relative importance, shown in Table 1, measured, first, according to the number of plants using them and, second, according to the amount of metal melted in them.

Table 1

	Per Cent of Total	
	Number of Plants	Metal Melted
Crucible furnaces, using coal or coke	30.1	18.5
Crucible furnaces, using oil or gas	30.1	9.0
Open-flame furnaces, using oil or gas	49.4	39.0
Arc electric furnaces	26.5	19.5
Induction electric furnaces	7.2	4.5
Miscellaneous	...	9.5

The first column does not add to one hundred per cent for the reason that many plants use more than one type of furnace. The second column expresses in percentages the proportion of the total tonnage melted in each type of furnace.

If we accept the data supplied by the foundries answering the questionnaire as representative of the brass foundry industry as a whole, it can be concluded that the five furnace types which we have selected as most important, melt 90 per cent of the total foundry metal and that the refractory problems involved in the use of these furnaces are of the most general interest. Among these the induction electric furnace has been included not because of its present importance, which is slight, but because difficulty with refractories has been largely instrumental in keeping this furnace out of the foundry field. In the rolling mill industry less serious refractory problems have been encountered and the induction furnace has taken a commanding position.

The qualities required from the refractory structures in these various furnace types are exceedingly varied in their nature. The following list of these qualities serves to enumerate them but does not necessarily rank them according to their relative importance.

1. Refractoriness.
2. Resistance to spalling.
3. Resistance to slag.
4. Resistance to metal penetration.
5. Resistance to penetration by liquid or gaseous fuels.
6. Resistance to chemical action by various metals and fluxes.
7. Behavior in oxidizing or reducing atmospheres.
8. Heat conductivity.
9. Electrical conductivity.
10. Mechanical strength and cohesiveness.
11. Ease and convenience of use.

These factors vary in importance according to the type of furnace under discussion. Some of them are essential in every case while others are limited in their importance to conditions peculiar to a single furnace type. In discussing the refractory problems which must be met in the use of different furnaces, an

attempt will be made to indicate the comparative importance of each factor and the degree to which the requirement is satisfied in ordinary good practice.

Crucible Furnaces Using Solid Fuel

This type is probably of diminishing importance but still melts close to 20 per cent of the total foundry melt. Coke is the usual fuel. Refractories come in contact with the fuel but not with the metal.

The linings of pit fires are ordinarily built of cupola blocks, ordinary fire-brick shapes, or various plastic mixtures rammed into place. Brick made of mixtures containing carborundum are sometimes used. The life of the linings varies from 100 to 1500 heats in different plants. The committee's survey showed an average of 670 heats. From 1000 to 1200 heats should probably be rated as good practice under usual conditions where the aver-

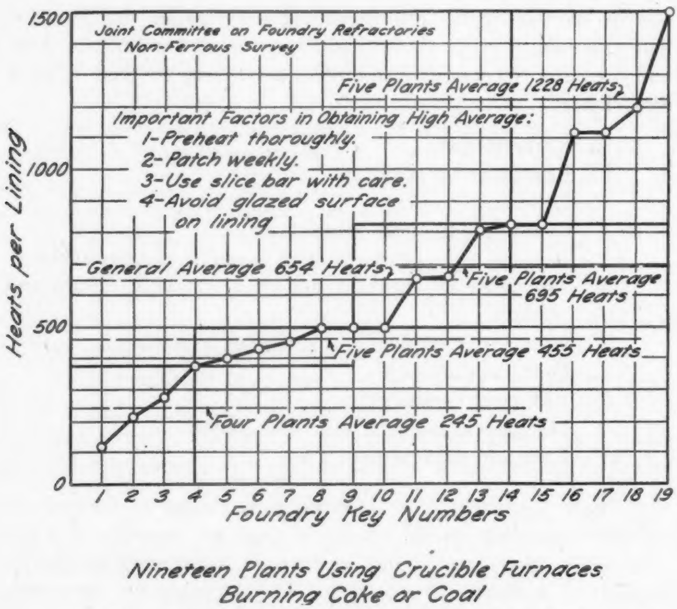


FIG. 1—DATA ON SOLID FUEL CRUCIBLE FURNACES

age daily output from each pit is four or five heats. In some plants six or seven heats are melted in each pit daily and a somewhat shorter life might naturally be expected from the lining.

The most rapid wear occurs in the ash zone and is due to the fusing of slag and clinkers to the lining. In cleaning the fires these adhering clinkers are chipped off with a bar and this process gradually destroys the lining. This is also the region of most intense heat. Weekly patching of the linings is profitable although not so essential as in furnaces which use linings both more expensive and more difficult to install.

Pit linings should be of great mechanical strength to resist the action of the poker. They should be resistant to the silicious slag formed by fusion of the ash and should not crack. Average conditions would be greatly improved by the use of a slag-resisting material more refractory than common fire brick. Rammed-up lining of carborundum mixtures, if skillfully installed, are very durable as are also certain grades of brick containing carborundum. As a rule, the handling of the bar in tending the fire and in cleaning the pits largely determines the life of the lining. Variations in the skill of the furnace man are so great as to obscure the effect of other factors when an attempt is made to compare results obtained in different plants.

It should be noted that the word "carborundum" is used in this paper as a commonly understood term denoting commercial silicon carbide, not as the trade name for the product of a particular company.

Crucible Furnaces Using Oil or Gas

At the time of the committee's survey furnaces of this type were melting less than 10 per cent of the total although they were widely used as reserve equipment in plants depending on other furnace types for the bulk of their work. It is probable that this furnace type is at least holding its own or possibly slightly increasing in relative importance. The usual fuel has been oil although the gas companies are now working quite actively in this field.

In this type of furnace the refractories are directly exposed to the flame but do not come in contact with metal or slags. Such considerations as heat conductivity or slag resistance are

of little importance. Twenty-five foundries reported a lining life varying from 100 to 2,000 heats, with an average of 775. Twelve to fifteen hundred should be rated as good practice. The destruction of the lining is due to the cutting action of the flame and to the decomposition of unburned fuel which finds its way into the cracks and pores of the refractory. This results in what can best be described as "rotting" of the brick.

The linings of oil crucible furnaces are usually made from common fire brick or from a rammed plastic mixture, the latter usually containing a considerable proportion of carborundum. It appears from the committee's data that such a rammed lining outlasts a fire-brick lining by about 50 per cent. A glazed surface on the lining before it is put in service is an advantage. Pre-

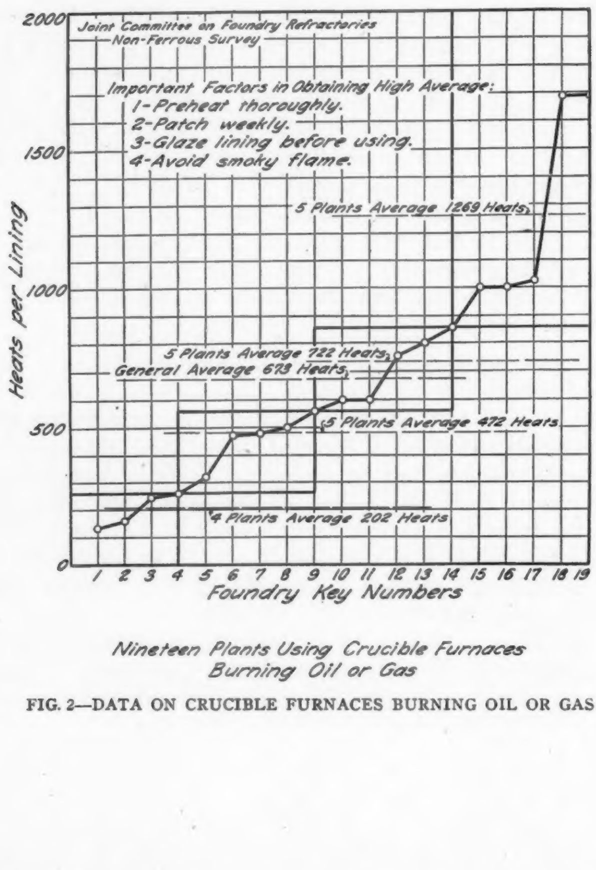


FIG. 2—DATA ON CRUCIBLE FURNACES BURNING OIL OR GAS

heating and regular patching help to increase the life of the lining; neither is widely practiced.

Open-Flame Furnaces

Replies received by the committee indicated that about 50 per cent of the plants reporting made at least partial use of this type of furnace for melting nearly 40 per cent of the total metal melted. This proportion was more than equal to the next two most important furnace types combined. Although still of great importance it seems probable that furnaces of this character are gradually losing ground to the electric furnace.

Most of the factors previously mentioned need to be considered in connection with the use of these furnaces. The refractories are exposed to direct action by flame, metal, slags and fluxes. Heat conductivity is of comparatively small importance and electrical conductivity naturally of no importance at all. Failure of the lining is due to:

1. Spalling.
2. Cutting action of the flame.
3. Fluxing action of floating slags and fluxes.
4. Fluxing action of particles of slag thrown against the refractory by the blast of the flame.
5. Mechanical injury due to charging heavy pieces of metal.
6. Mechanical injury due to chipping out slag.

Furnaces of this type are built in differing shapes. Cylindrical furnaces are usually lined with brick; in egg-shaped or oval furnaces rammed linings are common although furnaces lined partly with brick and partly with plastic mixtures are rather more frequent. From the data received by the committee brick linings seem to have rather the better of the argument, possibly because more skill is required to properly install a rammed lining.

Reports indicated a lining life of 75 to 1,900 heats, with an average of 520. Nothing less than 1,000 heats should be considered good practice and 1,500 heats is a reasonable goal.

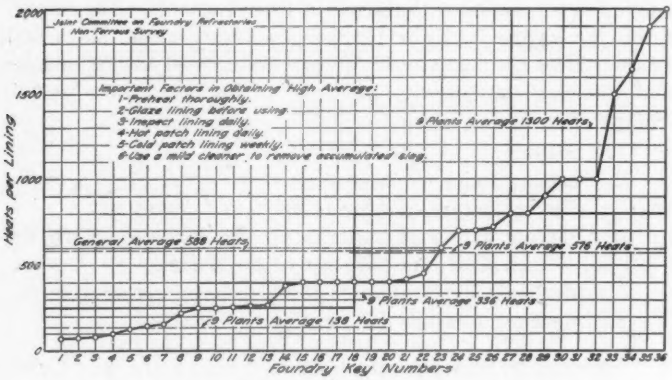
In all furnaces which expose their refractories to direct contact with metal and slag, the nature of the metal and operating methods are important factors. The following is quoted

directly from the committee's report as fundamentally true under nearly all conditions.

"Best results are obtained by preheating with wood or charcoal, then applying a slow oil fire for several hours. Glazing the surface of the lining before service is beneficial.

"Periodical inspection and patching is much better than 'patching as needed.' The best combination seems to be daily hot patching plus weekly cold patching.

"The composition of the metal does not seem to be of great importance, although very high lead undoubtedly has some detrimental effect.



Thirty-Six Plants Using Open Flame Furnaces

FIG. 3—DATA ON OPEN FLAME FURNACES

"The use of fluxes is hard on the lining, lime and fluorspar being particularly bad. Really dirty metal, particularly if contaminated with oil or grease, is harmful to the refractory. Turnings, if reasonably clean, have no detrimental effect.

"The slag probem is not likely to be serious if the furnaces are run steadily at a high temperature. Small doses of a mild cleaner (probably with a fluorspar base, or borax) are effective under these conditions. More drastic measures, such as the use of salt, lime and flourspar, or high heat in an empty furnace, are destructive."

An exception to one of the above statements should be noted, in the light of more recent experience. Plastic mixtures containing carborundum have proved to be unusually durable under some conditions but cannot safely be used with alloys containing more than five per cent of lead. Action between lead and the carborundum not only shortens the life of the lining but also tends to contaminate the metal. This disadvantage becomes very serious when active cleaners or fluxes are used.

Indirect-Arc Electric Furnaces

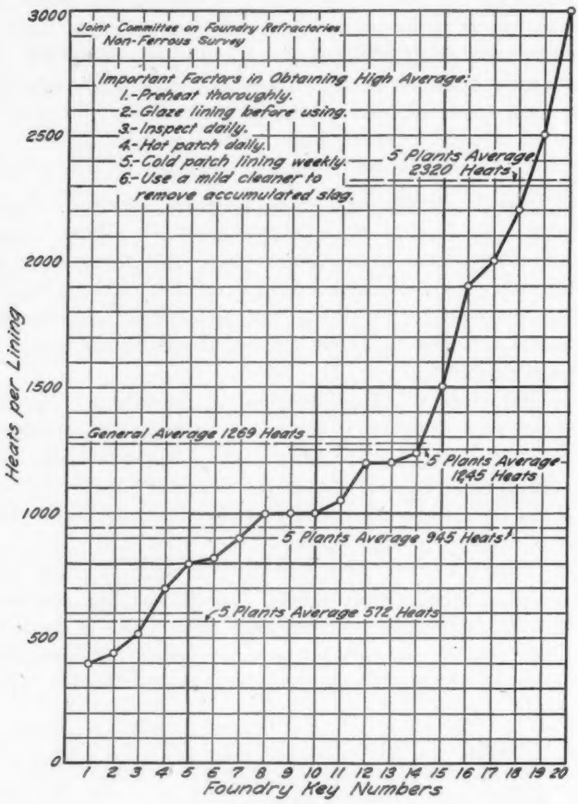
This type has made very rapid progress, especially during the past two or three years. The committee's report showed more than 25 per cent of the plants using this furnace to melt about 20 per cent of the total foundry melt. Since the time of the report these proportions have increased greatly and can now be estimated as more nearly on a par with the figures given for open-flame furnaces.

The refractory problems involved in furnaces of this type are interesting and important, including, as they do, every factor mentioned in the early part of this paper. The rapidly increasing importance of this furnace makes the development of improved refractories for its use a matter of great interest to both refractory manufacturer and furnace user.

The lining life reported by arc-furnace users averaged 1,350 heats, varying from 400 to 4,000. Under average conditions 1,000 to 1,500 heats may be rated as good practice in the larger sizes, 1,500 to 2,000 in sizes of capacity below 500 pounds of metal per heat. Destruction of the lining results from the following factors:

1. Spalling.
2. Fluxing action of floating slags.
3. Mechanical injury in charging.
4. Mechanical injury in chipping out slag.
5. Burning out of end walls due to broken electrodes.
6. Fusing of roof due to delayed or insufficient rocking.
7. Penetration of metallic vapors or oil into the refractories.

Refractories containing high percentages of carborundum are very durable in this type of furnace but, because of their



Twenty Plants Using Arc-Type Furnaces

FIG. 4—DATA ON ARC TYPE FURNACES

high heat conductivity, must be backed up with added heat insulation. Such linings are very refractory and are particularly resistant to spalling and vapor penetration. As has already been noted under the head of open-flame furnaces linings containing carborundum cannot safely be used with leaded alloys and are vigorously attacked by fluxes and metal cleaners, although unaffected by silicious slags. They can be used to excellent advantage in melting high-zinc alloys containing little or no lead.

In most foundries a high-grade diaspore brick is used and spalling is the principal difficulty encountered. Such a brick answers most requirements and, in particular, does not react chemically with the metal. It is necessary to avoid patching materials which contain high percentages of carborundum. There is some evidence that sodium silicate is also undesirable but the importance of this is uncertain, since many plants using sodium silicate extensively have never had any difficulty with it.

Periodical patching of indirect-arc furnaces is almost universal, although this practice varies widely in detail. Preheating is universal but differs in extent and duration in different plants.

Induction Electric Furnaces

Furnaces of this type are not used extensively for melting foundry red brass, reports at the time of the survey showing less than 5 per cent of the total melt handled by this furnace, and nearly all of this was foundry yellow brass. The average lining life varied from 700 to 1,500 heats and averaged 990. Plastic mixtures of comparatively low refractoriness are used; at yellow brass temperatures such linings are quite reliable and long lived. The refractory lining in the V shaped heating channel of the induction furnace is very thin. Rapid melting requires that the metal temperature at or near the point of the V should exceed the normal pouring temperature of the alloy by perhaps 400 or 500 degrees Fahr. At this point the lining must be sufficiently refractory, very dense in order to resist penetration by the molten metal, and must under no circumstances develop even superficial cracks as a result of temperature changes. Since the electric current passes through the metal in direct contact with the lining it goes without saying that carborundum or other materials of high

electrical conductivity cannot be used. Any considerable proportion of lead in the alloy has a tendency to cause excessive penetration of metal into the lining and such alloys destroy the lining rapidly. The relatively high pouring temperatures necessary for red brass make it difficult to use in the heating channel a refractory sufficiently dense to withstand metal penetration and erosion.

The applicability of the induction furnace to foundry work would be greatly increased if it could be furnished with a lining which would be sufficiently durable when used for melting red brass alloys containing moderate percentages (say 5 to 10 per cent) of lead.

Improved Practice for Combustion Furnaces

The charts given in this paper show comparative data from the report of the Survey Committee indicating the variation in lining life experienced by different plants, classified according to the type of furnace. It is apparent at a glance that the average experience is much less satisfactory than it ought to be, judging by the experience of those plants which have given this matter most attention. This is particularly true of the fuel-fired furnaces, somewhat less true of the electric furnaces. In the latter case more accurate records are kept, more expensive refractories used and more pains taken to get the best possible results. This is due partly to the greater cost of lining electric furnaces, partly to the educational efforts of the furnace manufacturers.

In furnaces using fuel it would appear most profitable for foundries which find that they are getting a less-than-average lining life to improve their results by following the practice which has been worked out so successfully by a few. This includes particularly pre-heating, patching and care by the furnace operators. Accurate records of lining life must be kept if such a program is to be successful. The use of expensive refractory materials is not ordinarily justified, although carborundum mixtures can be used to advantage in many cases. The refractory manufacturer has much to gain by helping his customer get better results through improved practice, little to gain by the development of expensive refractories utilizing rare or costly materials.

Electric Furnaces

In the case of electric furnaces the use of costly refractories is often economically sound. Lining such furnaces and preparing new linings for service are comparatively expensive operations, involving a loss of production which is particularly serious because of the large investment in the furnace equipment. On the other hand, electric furnace operation lends itself to very long lining life under favorable conditions, so that a lining of high cost per pound may easily be cheaper to use than an inherently cheaper but less durable material. Materials of this character which are either in common use or the subject of active experiment include kaolin-asbestos mixtures, diaspore clays, carborundum, sillimanite and chrome ore. The first named is not sufficiently refractory for most electric furnace service but has been very successfully used in the induction furnace for melting yellow brass.

Diaspore linings in the form of shapes have been standard for the indirect-arc furnace and give fairly good service. Under severe conditions they spall rather badly and they will not resist alkaline slags. Plastic mixtures of this composition have not been sufficiently tested to give a definite indication of their value.

Plastic mixtures containing carborundum have already been mentioned in some detail. Varying experience with this material offers a striking example of inconsistency in results obtained by different users. In many respects it is an ideal brass furnace refractory, since it is almost entirely free from cracking and readily forms a vitrified surface which is very resistant to heat or ordinary wear. With high-zinc alloys containing little or no lead its resistance to metal penetration recommends it highly and its use meets with almost unvarying success. With percentages of lead in excess of three per cent various users report most radically different results. Some have no difficulty at all, others get good results part of the time, while some have constant trouble with silicon contamination, accompanied by the characteristic formation of drossy lead silicide and segregation in the brass itself. The latter causes the metal to have a loose, open structure resulting in castings which are weak and leak under pressure.

The answer seems to be that carborundum in contact with lead always gives trouble (in the reducing atmosphere of the arc

furnace), provided a true contact exists between the grains of carborundum and the metal. A well glazed lining in which the carborundum crystals are protected by the glaze from attack by the lead will often run for long periods of time without the slightest sign of trouble. But this glaze is a delicate thing, easily destroyed and hard to replace. Any flux or cleaner which contains basic constituents removes the glaze very efficiently. A slight percentage of oil introduced with the metal charge destroys the glaze and makes it impossible for a new glaze to form until the furnace has completely freed itself of carbon. Removal of slag accumulations by strongly heating an empty furnace will sometimes result in a high percentage of defective castings for two or three days thereafter. These things make it difficult for the average foundry to take advantage of the excellent qualities of carborundum refractories.

Sillimanite—using this name to include also mullite, andalusite, etc.—offers distinct promise, but in plastic mixtures is difficult to bond without impairing its good qualities. Properly bonded it is very free from spalling, cracking and metal penetration. Brick made from this material are as yet too expensive for general use. Both the induction furnace and the arc furnace will benefit largely if the refractory manufacturer succeeds in perfecting plastic mixtures of this class.

Chrome-ore refractories are also difficult to bond and have not as yet seemed as promising as sillimanite or carborundum.

To the electric furnace user particularly this refractory problem is important. If the foundries will co-operate by keeping a careful record of their experience and compare notes freely both with their competitors and with the refractory manufacturers, there is some prospect of substantial improvement in the near future, since the refractory manufacturers seem inclined to be liberal in carrying out their share of the development work.

Influence of Carbon and Silicon Variations in Gray Cast Iron

By D. G. Anderson* and G. R. Bessmer,* Chicago, Ill.

It has long been recognized by producers of iron castings, particularly gray iron castings, that the carbon content and the silicon content, together with the relation between these two elements, have been the prime factors in determining the type of iron suitable for casting purposes, and in controlling the physical properties in the casting itself. During the past few years it has been realized that if possible the physical properties of gray iron should be improved, without materially affecting machinability or the manufacturing cost.

Possibilities which may be attained through efforts to improve cast iron are readily visualized by the recently developed pearlitic cast iron and the high test cast iron; one, however, is produced with considerable increase in cost, the other at the expense of machinability.

The improved properties attained in the above mentioned cast irons are primarily realized through the reduction in carbon content. However, the reduction of carbon content in cast iron must be regulated with caution. The effect of too great a reduction is quite drastic. In fact, cast iron was first discovered by smelting iron ore with an excess of carbon; in other words, without suf-

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ficient carbon in the iron we would not have what is known today as gray cast iron.

A search of the literature did not reveal data sufficiently complete and systematic to be used as a basis for further study of possibilities to improve gray cast iron by reducing the carbon content. A series of experiments, therefore, were conducted primarily of a laboratory nature.

The purpose of this paper is to record the results of our experiment, which we hope will prove of sufficient interest to others in furthering foundry studies.

The commercial opportunity of silicon variation and its decided influence on the state of carbon has been the major controlling medium in compounding gray iron mixtures suitable for a wide range of casting requirements. We know the various grades of gray iron by their silicon content and for this reason our series of tests are identified as classes of silicon content.

The base constituents of our mixtures were in the form of small ingots cast from cupola melted gray iron, and suitable in size for remelting in the small laboratory electric furnace.

The reduction of carbon was accomplished by the addition of alloy steels to the cast ingots, for example, silicon steel was added in required amounts because of its dual ability in reducing total carbon and maintaining the original silicon content of the cast. By this method it was possible to vary the carbon content in the same silicon classification and also hold all other elements within accepted commercial limits. Three commercially representative silicon content gray irons were selected, namely 1.10, 2.00 and 2.20 per cent; the silicon content was held constant in each respective series and the carbon content was gradually reduced and its effect recorded by chemical, physical and microscopic analysis.

The twenty-three heats embodying our range of tests were melted in an electric furnace of the induction type having a magnesia lining; the special lining was used to safeguard against the possibility of carbon absorption such as may be experienced from the more commonly used carbon base crucibles. The furnace used was an Ajax-Northrup high frequency induction type.

Test specimens in the form of one-half inch square bars eight inches long were selected in preference to the standard test bar, as

the one-half inch square bar is more nearly representative of our specific class of castings. The test bars were cast in sand molds, and molding conditions held as constant as possible by the sand being uniformly rammed and tempered over the entire range of casts. The test bars were gated on the end, two in one mold and placed in a horizontal position, and poured from one sprue, no risers being employed.

The temperature of the metal as it entered the mold ranged from 2560 to 2690 degrees Fahrenheit as determined by a disappearing filament type optical pyrometer. The temperature of the molten iron was raised as the carbon was reduced in order to maintain fluidity.

Table 1 shows chemical analysis and physical tests of the complete series of casts varying the carbon content from its normal amount in gray iron to below the normal amount in white cast iron without materially affecting the manganese, sulphur,

Table 1

Test Number	Silicon, Per Cent	Manganese, Per Cent	Sulphur, Per Cent	Phosphorus, Per Cent	Total Carbon, Per Cent	Combined Carbon, Per Cent	Deflection, in Inches	Transverse Strength, ½" Square Bar	Computed Trans. Strength 1¼" Dia. Bar	Tensile Strength, Lbs. per Sq In.	Brinell Hardness
1	1.10	0.55	.067	0.18	3.35	0.96	0.083	1105	5080	28200	218
2	1.10	0.55	.067	0.18	3.19	1.90	0.058	1100	5060	41400	316
3	1.10	0.55	.067	0.18	3.07	1.70	0.053	1066	4904	40600	300
5	1.10	0.55	.067	0.18	2.70	2.00	0.055	1375	6325	40600	280
6	1.10	0.55	.067	0.18	2.57	2.00	0.068	1508	6937	44800	316
7	1.10	0.55	.067	0.18	2.27	1.90	0.070	1631	7503	46800	286
11	2.00	0.55	0.06	0.70	3.38	0.71	0.090	885	4071	27200	200
12	2.00	0.55	0.06	0.70	3.27	0.68	0.076	960	4416	29000	178
13	2.00	0.55	0.06	0.70	3.05	0.64	0.084	991	4559	30000	186
14	2.00	0.55	0.06	0.70	3.05	0.60	0.082	992	4563	36600	210
15	2.00	0.55	0.06	0.70	2.54	0.70	0.081	1030	4738	40400	210
16	2.00	0.55	0.06	0.70	2.55	0.65	0.088	1058	4867	39600	186
17	2.00	0.55	0.06	0.70	2.40	0.79	0.080	1018	4683	39400	248
18	2.00	0.55	0.06	0.70	2.13	1.80	0.089	1181	5433	42000	238
19	2.00	0.55	0.06	0.70	1.91	1.70	0.112	1488	6845	50800	280
22	2.20	0.55	0.06	0.70	3.35	0.62	0.063	977	4494	31800	178
23	2.20	0.55	0.06	0.70	3.14	0.66	0.060	989	4550	37800	186
24	2.20	0.55	0.06	0.70	2.93	0.66	0.063	977	4494	38400	172
25	2.20	0.55	0.06	0.70	2.71	0.55	0.058	1005	4623	36000	200
26	2.20	0.55	0.06	0.70	2.55	0.53	0.058	1038	4775	38000	...
27	2.20	0.55	0.06	0.70	2.43	0.52	0.063	1066	4904	36800	186
28	2.20	0.55	0.06	0.70	2.16	1.50	0.060	1191	5480	42000	286
29	2.20	0.55	0.06	0.70	1.94	1.80	0.050	1289	5929	54000	286
30	2.20	0.55	0.06	0.70	1.83	1.70	0.053	1102	5069	39200	280

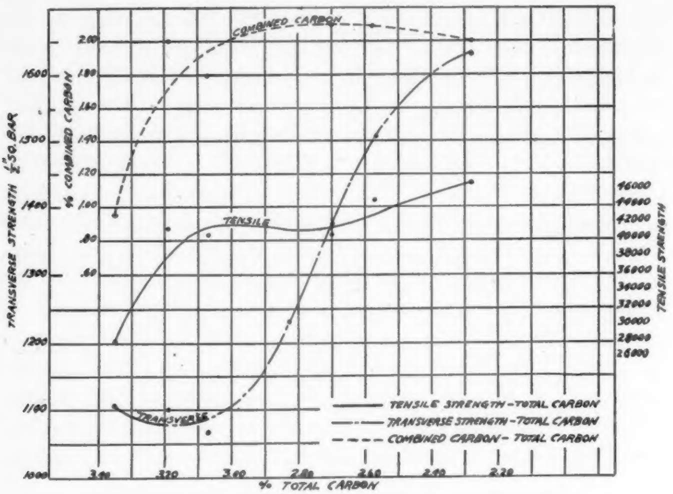

FIG. 1—DATA OF THE 1.10 PER CENT SILICON SERIES

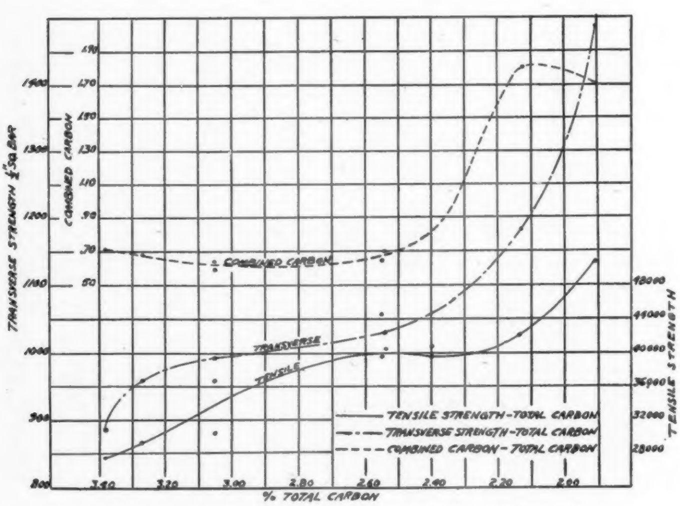

FIG. 2—DATA OF THE 2.00 PER CENT SILICON SERIES

phosphorus and silicon content. Standards of the United Steel Corporation for the sampling and analysis were used as follows:

Total carbon—Gravimetric Method
Combined carbon—Colormetric Method
Silicon—Drown's Method
Manganese—Persulphate—Arsenite Method
Phosphorus—Volumetric or Evolution Method
Sulphur—Volumetric or Evolution Method

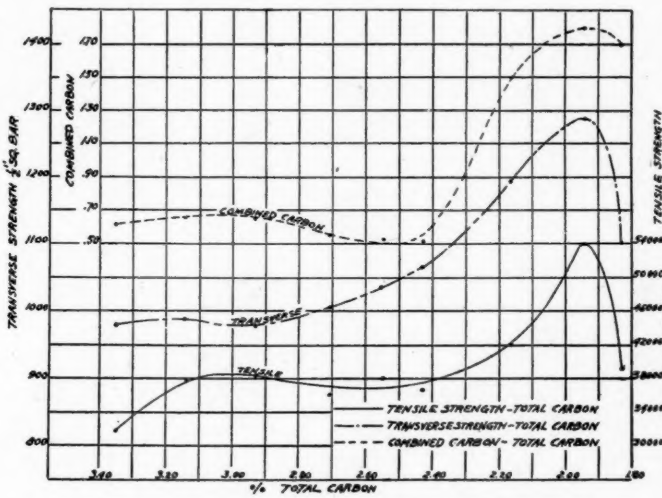

FIG. 3—DATA OF THE 2.20 PER CENT SILICON SERIES

The Brinell hardness determinations were made by the 3,000 kilogram weight and 10 millimeter ball. The computed transverse strength gives a ready means of comparison with standard test bar data. The one-half inch square test bars, eight inches long, were suspended on six inch centers for the transverse tests.

The 1.10 per cent silicon series chart, Fig. 1, shows the sudden rise of combined carbon and the increased hardness produced when total carbon is reduced in relatively low silicon gray irons.

The 2.00 per cent silicon series chart, Fig. 2, shows no appreciable increase in combined carbon until the total carbon is

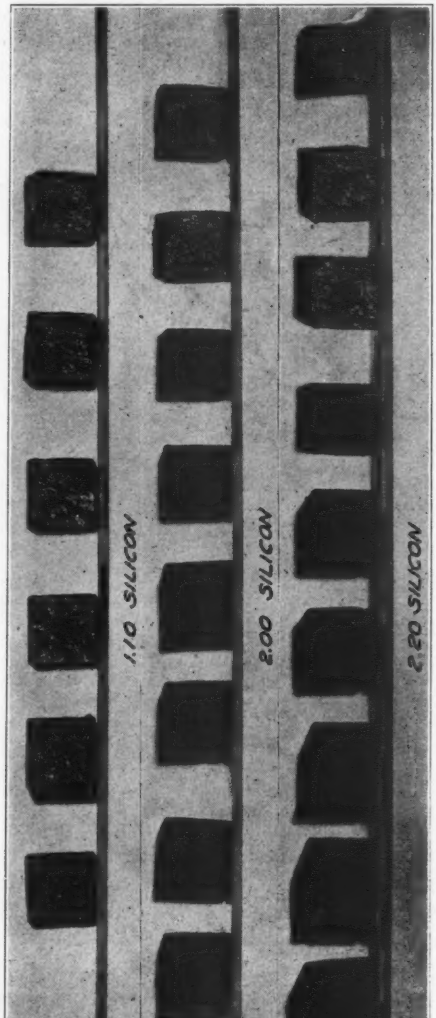

FIG. 4—BROKEN TEST SPECIMENS SHOWING HOW THE GRAIN IS REFINED

reduced to less than 2.60 per cent. The chart also indicates the resulting increase in transverse and tensile strengths.

The 2.20 per cent silicon series chart, Fig. 3, shows practically no change of combined carbon until the total carbon is reduced to less than 2.50 per cent. The chart also shows that the presence of too great an amount of silicon counteracts the advantages of reducing the carbon content noted in the 2 per cent silicon iron.

Fig. 4, a photograph of the broken test specimens, shows how

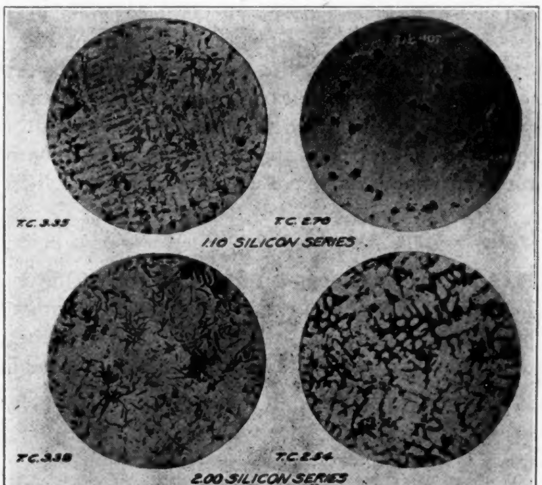

FIG. 5—PHOTO-MICROGRAPHS OF IRONS—REDUCED ½ FROM ORIGINAL MAGNIFICATION

the grain is gradually refined, as the carbon is reduced, and also shows changes to the mottled and later the white cast iron.

Since we are confining our study to silicon and carbon relation the microscopic study was conducted from unetched samples, as the condition of carbon may be more readily interpreted in the photomicrograph.

Part of the carbon is recognized as being present in a combined form and part as free carbon or graphite. The graphite is the element which imparts the color to gray iron and forms in soft flakes which act as planes of weakness. The condition and distribution of these graphite flakes in general controls the physical properties of the casting. The photomicrographs of Fig. 5 show that the free carbon in normal carbon content irons is present as long black flakes and forms cleavage planes. As the carbon content is reduced it will be noted that the free carbon formation is changed from flakes to round shapes, making the structure of the iron proper stronger, which is substantiated by the physical test.

Conclusions

That total carbon content of gray cast iron of the 2 per cent or higher silicon type may be somewhat reduced without materially increasing the amount of combined carbon in the casting. This reduction of carbon for these irons results in some improvement of physical properties.

The Surface Conditions of Castings as Affected by Core-Sand Mixtures

By H. L. Campbell,* Ann Arbor, Mich.

Abstract

An investigation has been made to obtain information on the factors which control the smoothness of the surfaces of castings which are formed by cores. The plan for this research was to prepare dry-sand cores from definite combinations of sand and to use these cores as parts of molds. After pouring the metals in contact with the core specimens, the surfaces of the castings were cleaned and examined for relative smoothness. Observations on the effects of different sands and other materials used in core-sand mixtures on the "finish" of castings are recorded in this report.

In the selection of materials for core-sand mixtures, it is important to consider the effects of these mixtures on the surfaces of the castings which are to be formed by the cores. As a rule, the surface conditions of metal castings are dependent on the smoothness of the cores to which the metal is exposed. This influence is particularly noticeable with castings which are made of brass and other alloys which are very fluid at their pouring temperatures. Steel is quite viscous when it is poured into molds and does not fill the minute cavities on the surfaces of sand cores. The higher the temperature at which cast iron is poured, the greater will be the tendency for the metal to fill the voids between the sand grains on the surfaces of the cores.

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prepare dry-sand cores from definite combinations of sand and to use these cores as parts of molds. After pouring the metals in contact with the core specimens, the surfaces of the castings were cleaned and examined for relative smoothness. Observations on the effects of different sands and other materials used in core-sand mixtures on the "finish" of castings are recorded in this report.

The distribution of the grains of different sizes in a sand will determine to a large extent the surface conditions of the cores made with this sand. Smooth surfaces can readily be produced when the core-sand mixture contains only very fine grains. The openings between large, uniform grains of sand cause the surfaces of cores to be rough. When large and small sand grains are present in a mixture, the small grains tend to fill the spaces between the larger grains and to form a smoother surface than is formed when only large grains of sand are used.

The greater the pressure applied in forcing the sand mixture into a core box, the more smooth will the cores become. Also, the smoothness of the internal surfaces of a core box will affect the surfaces of cores made in this box. If any core-sand sticks within the core box when it is removed from the core, a rough surface will be produced on the core.

If smooth surfaces were the only requirement of cores, the preparation of core-sand mixtures would be a comparatively simple matter. However, it is necessary that cores have sufficient permeability to permit the gases which are generated within the cores to escape freely when metal is poured into the molds. In order to obtain this permeability, it is necessary to have open spaces between the sand grains in the cores.

There is a difference between the properties of permeability and porosity of sand mixtures. The proportion of open spaces between sand grains of uniform size is practically the same for sand containing either large or small grains. However, the capacity of any sand to permit gases to filter through it depends upon the continuity and the size of the openings between the sand grains. A fine sand offers more resistance to the flow of gases through the openings between grains than does a coarse sand. Therefore, the permeability of cores made with sands having small grain sizes is relatively low.

The core-sand mixtures used at some foundries contain proportions of materials such as silica flour, rattler dust, or a fine sand, which are used to fill the voids between the grains of a coarser core sand. By this means, an attempt is made to increase the green-bond strength of the mixture as well as to produce smooth surfaces on the cores. While the green-bond strength may be increased to some extent by the addition of fine-grained materials to oil-sand mixtures, the permeability and dry-bond strength of the resulting cores are generally seriously impaired.

In order to obtain definite information on the effects of different core-sand mixtures on the surfaces of metal castings, a special mold was designed which permitted a test specimen to be cast in contact with dry-sand cores. The mold was formed from two cores which were clamped together in a vertical position. The double core box and the cores which served as the mold are shown in Fig. 1. Within each half of the mold, a circular cavity five inches in diameter and twenty-one thirty-seconds of an inch deep was provided. Core specimens which were prepared under standardized conditions were placed in these cavities, so as to allow a space five-sixteenths of an inch between the faces of the cores when the mold was assembled for pouring. A pouring basin and gate were formed in the mold cores, as is shown in the photograph.

Mixtures Used in Core Specimens

In this investigation which aims to determine the factors which affect the "finish" on castings, various combinations of sand were used in the preparation of the insert core specimens. In one series of tests, silica sand of a limited grain size was used. Washed and dried silica sand was classified by passing it through a set of sieves of Bureau of Standards sizes. The sand retained on the 30, 40, 50, 60, 70 and 140 mesh sieves was used in core-sand mixtures.

Another series of core specimens was prepared from mixtures containing different proportions of lake sand and a sand of small grain size known as "bank" sand. Silica flour was added in definite proportions to some of the mixtures used in preparing core specimens. Insert cores were also made with sands containing a variety of grain sizes.

In the preparation of the mixtures used in core specimens, a paddle-type mixer was used. Raw linseed oil was added to the sand in the ratio of one volume of oil to fifty volumes of sand. Each batch was then mixed for two minutes. This was followed by the addition of water in amount equal to four per cent of the volume of dry sand, except in those mixtures which required more water to develop maximum green-bond strength. The mixing was then continued for a period of three minutes. From each batch containing two thousand cubic centimeters of sand, six insert core specimens, two permeability test specimens, and four

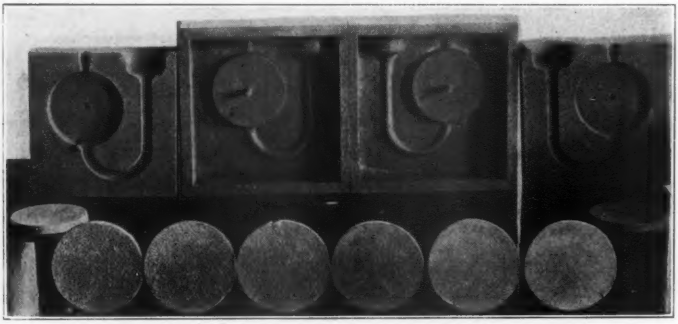

FIG. 1—SHOWING CORE BOXES, CORES AND CASTINGS

transverse test specimens were obtained. These cores were baked for one hour at 425 degrees Fahr.

The Preparation of Core Specimens

The core specimens were prepared on the core-making machine, which is used regularly for making test specimens for the measurement of dry-bond strength, green-bond strength, and the permeability of cores.* In this case, a core box having a circular opening five inches in diameter and one-half inch deep was mounted on the core-making machine and a hopper was provided having a height of three inches above the core box. The core-sand mixture was placed loosely in the hopper and core-box. By

*Campbell, H. L., *The Qualities of Commercial Core Oils*, Trans. American Foundrymen's Association, Vol. 33, pp. 72-82 (1926).

raising the core box and hopper a distance of twelve inches and allowing them to drop, the jarring action packed the sand into the core box. Uniform specimens were prepared by five blows on the core-making machine. The excess sand over the amount required to fill the core box was removed and the core specimen was turned out onto a core plate. One of the flat surfaces on each specimen was formed by contact with the bottom of the core box and the opposite surface was produced when the excess sand was cut away from the core.

The Preparation and Pouring of the Molds

The cores which formed the molds were made in a double core box, which was mounted on a molding machine. The core box and two mold cores are shown in Fig. 1. The mixture used in these cores consisted of lake sand bonded with raw linseed oil. In preparing the mold for pouring, the insert cores were pasted in the cavities which were provided in the mold cores, and then the two halves of each mold were pasted and clamped together.

An attempt was made to pour the molds which contained each series of core specimens at as near the same temperature as possible. The metal used in these tests included gray cast iron, electric furnace steel, and red brass. The metal specimens were allowed to remain in the molds until they were at room temperature. After removing the gates from the castings, the surfaces were sandblasted and the specimens were then ready for inspection.

Standards of "Finish" on Castings

The metal surfaces which were produced by contact with core specimens containing silica sand of six different grain sizes were used as standards by which the relative smoothness of other metal surfaces was established. A definite gradation of "finish" was observed on the surfaces of the brass and cast-iron specimens which were formed by contact with cores made with these six sizes of sand. The surfaces on the castings which were formed by cores containing silica sand which passed a 20-mesh sieve and was retained on a 30-mesh sieve were very rough, while the surfaces of the castings poured in contact with cores containing 70

to 140-mesh sand were quite smooth. The variations in smoothness of the steel specimens were not as pronounced as was found with the other metals. When these surfaces were examined with the aid of a binocular microscope, the differences in contour of the surfaces of the specimens were clearly indicated. The same conditions were observed on the corresponding core surfaces. In Fig. 1 the brass specimens which were cast in contact with cores made with sands having six different grain sizes are shown, arranged in order of the size of the sand used in the cores.

Effects of Bank Sand Additions to Core-Sand Mixtures

A bank sand contains rounded grains of silica which will generally pass a 70-mesh sieve. This sand is sometimes used in mixtures with lake sand which has a range of grain size of 40 to 70. The purposes for the additions of bank sand to core-sand mixtures are probably to increase the green-bond strength, and to produce smooth surfaces on the cores. In this investigation, core specimens were prepared from mixtures containing 0, 10, 20 and 30 per cent by weight of bank sand. The castings which were made in contact with these core specimens showed practically no differences in the smoothness of their surfaces. The bank sand additions decreased the dry-bond strength and also decreased the permeability of the oil-sand cores, while the green-bond strength of the mixtures containing bank sand increased only to a small extent.

Core-Sand Mixtures Containing Silica Flour

Silica flour, which is obtained by fine grinding of quartz rock or silica sand, is used to assist in producing smooth surfaces on cores, and to raise the green-bond strength of core-sand mixtures. Proportions of silica flour as high as 40 per cent of the total weight of the core sand have been specified in some foundry mixtures. Core specimens were prepared from mixtures containing from 4 to 30 per cent by weight of silica flour, and castings were poured in contact with these cores. An examination of the surfaces of these castings showed that very little improvement was obtained in the smoothness of the metal surfaces which were cast in contact with the cores containing silica flour, over the smooth-

ness of the surfaces formed by cores made with the same sand without the silica flour additions. Furthermore, it was found that the permeability and the dry-bond strength of the oil-sand cores were decreased considerably by the presence of the silica flour.

Core Sands Containing Different Grain Sizes

The predominating sizes of the sand used in cores determine to a large extent the surface conditions of the castings made in contact with these cores. Smoother surfaces can be produced by the use of a core-sand containing grains of 60 to 70-mesh size than can be obtained with a sand having a predominating grain size of 40 to 50-mesh. Core-sand mixtures containing sand having a variety of grain sizes ranging from fine to coarse, cannot be used to advantage in making cores which must have smooth surfaces. It appears that the spaces between the larger grains are not completely filled by the smaller grains of sand. If it were possible to produce a dense, compact mass of sand in a core by using grains of different sizes, the cores would have only limited application on account of the lack of permeability in these cores.

The brass and iron castings which were poured in contact with those surfaces of the core specimens which were formed in contact with the bottom of the core box were found to be much smoother than the castings which were made in contact with the other faces of the core specimens. When the excess sand was separated from the core specimens during their preparation, rough surfaces were produced on these faces of the cores. The larger the sand grains in the core-sand mixtures, the more uneven will the cut-off sections become. When castings with smooth "finish" are required, only those surfaces of cores which have been formed by the core box should be used in contact with the metal. In cases where it is necessary to make cores to size by filing or grinding, a sand having a fine, uniform grain size will be most satisfactory for the preparation of the cores.

Conclusions

1. The results of these investigations indicate that the most desirable properties for dry-sand cores are obtained when the

core sand contains grains of uniform size and of sufficient fineness to produce the required smoothness on the surfaces of the cores.

2. The smoothness of castings which are formed by contact with cores will be practically the same as the smoothness of the cores, provided the metal is sufficiently fluid when it is poured to fill the minute cavities on the cores. In all cases where smooth surfaces are required on castings the cores which form these surfaces must be smooth.

3. The additions of bank sand or other finely divided materials to core-sand mixtures within reasonable proportions do not improve to any appreciable extent the smoothness of the surfaces of castings which are made in contact with these cores.

Acknowledgment

In this research on the factors which affect the "finish" on metal castings, assistance was obtained from the Department of Engineering Shops and the Engineering Research Department of the University of Michigan. We are also indebted to the Detroit Steel Castings Company for providing the cast-steel specimens used in these investigations.

On Research Problems of the Gray Iron Foundry

By J. W. Bolton,* Cincinnati, Ohio

Synopsis of Paper

Lack of complete knowledge of the engineering properties of gray iron has deterred engineers from most extensive utilization of this metal. Organized research, which has proved successful in other fields, can be applied with advantage toward the solution of this problem. Such work has been initiated by the American Foundrymen's Association.

Gray iron is not a single metal, but a *series of alloys,* varying widely in composition and physical properties. Gray irons may be classified into 40 (or more) groups, according to their *silicon and carbon content.* The irons within these 40 groups are to be subdivided further according to their *cooling rates.* Difficulty of obtaining exact data on *absolute* cooling rates are enumerated. The ratio $\frac{\textit{volume}}{\textit{surface area}}$ is used to define *relative* cooling rate. This ratio has proved very useful, although discretion is needed when applying it.

The users of gray iron need to know the properties of the metal *in the castings.* Several examples are cited which show that it may be possible to determine some of the properties of castings by means of properly chosen test bars. Here, as in case of all

*The Lunkenheimer Co.

testing work, it is necessary that the limitations of the tests be understood and their interpretation be carefully made. A portion of the paper is devoted to discussion of several test methods. The value and limitations of the tensile tests are enumerated. A new shear testing method is offered, the method being a refinement of that originally proposed by the late George Elliott. A tensile-shear relationship is given. Limitations of the brinell test are enumerated. A new uniformity test is described briefly. Brief remarks are included on machinability, wear, heat treatment, corrosion resistance, rigidity and properties at elevated temperatures.

The balance of the paper is given to discussion of the properties of various groups of iron.

The writer points out that the ratio *per cent carbon* $+$ *0.3* $\times$ *per cent silicon* indicates the position of the metal in the iron carbon diagram. He shows that this is a good formula for use in plotting strength values against cumulative percentages of carbon and silicon. The effect of steel *per se* is noted.

The conclusion is that accumulation of more extensive fundamental research may enable great simplication of the present chaos of gray iron metallurgy. To do this it is necessary to consider irons in *groups,* to get away from the illogical *arbitration* bar for use in research work, and to accumulate more data on *correlation* of test results to properties and service of castings.

Part 1

What the Foundryman Sells

The foundryman sells castings—

a. Of a certain shape and weight,
b. Made of a complex material, cast iron,
c. With certain standards of workmanship, such as finish, accuracy, etc.,
d. To be delivered at a specified time,
e. At a certain price per piece or per pound,
f. To meet certain fabricating and engineering demands.

In short, he sells, *service,* and, as do all intelligent manufacturers, he strives to be able to give most *service per dollar.* To a large degree he is a purveyor of a material, a metal—*Cast Iron.* The engineer (who is responsible for choice of material in design)

knows that the proper material for any specific application is that material which fully satisfies the service demands at the least cost. It is obvious, then, that the more the foundryman and engineer *know* about cast iron, the more intelligently it will be used—and probably this will result in increased applications.

Competition

The past twenty-five years have seen an active industrial battle between steel castings foundries and malleable castings foundries, and iron castings foundries. In so far as competition with iron castings is concerned, steel and malleable have been having the best of the argument. In many cases replacement of iron by steel and malleable is proper. However, some observers feel that iron foundries have lost more business than they should. Perhaps this is so. At least we are awakening to the fact that properly made iron is not an "unreliable material"; that it has some hitherto unsuspected possibilities.

Three Voids

Three things were lacking in the average old time foundry, namely—

(1) *Production Methods and Equipment.*
(2) *Accurate Costing.*
(3) *Knowledge of the Engineering Properties of the Iron.*

Happily, progressive iron foundrymen of today are up to the minute in utilizing production equipment and methods. The American Foundrymen's Association and the trade press are making the necessity of proper cost accounting methods clear to the foundrymen. This is minimizing cut-throat competition and promoting a spirit of friendly co-operation. Ever alert to foundrymen's needs, the American Foundrymen's Association also is giving careful consideration to ways and means of promoting wider knowledge of the engineering properties of cast iron. In undertaking such research the A. F. A. is doing much toward helping foundrymen *to give most service per dollar*—for the foundryman must know his product well in order to combat the old and deep-rooted opinion that *cast iron is an unreliable material.*

System Necessary

Progress is not the usual reward of haphazard efforts—in research as elsewhere. Scientific implies systematic. This paper is a preliminary one. It contains an outline of a scheme for research in cast iron, some preliminary data is included, and some tentative generalities drawn relative to the inter-relationship of certain properties of cast iron.

Classification of Irons

Gray iron is not gray iron, an alloy. Gray iron is a *series of alloys of iron, carbon, and silicon,* and other metals and metalloids. It is possible to obtain commercial gray irons anywhere from 10,000 pounds per square inch tensile strength to over 60,000 —a 600 per cent variation. Carbon content ranges from 2.20 to nearly 4.00 per cent, phosphorus .15 to 1.00, silicon .60 to 3.00, with corresponding wide variations in engineering properties. In any research work, then, it is very necessary to specify very clearly *what grade* of iron we are talking about. Further, the engineers need to know the properties of the iron *in the casting.* Thus a major problem is to *classify irons into various grades, and to find out what these grades will do in various castings.*

Classification by Composition and Cooling Rate

Experience and research indicate that the engineering properties of cast iron depend largely upon (a) the composition of the metal; and (b) its cooling rate when poured into castings.[1]

Silicon and Carbon

The most important elements are *silicon and carbon.*

The general effects of silicon are rather widely known, thanks to the splendid work of Prof. Turner and other able investigators. Pig irons are graded by silicon content and all good foundrymen make use of silicon analyses.

The late Prof. Howe was among the first to point out the profound effects of carbon on the mechanical properties of cast iron. Unfortunately, until some fifteen years ago, the analytical determination of the total carbon content of cast iron was a tedious

[1] In order to retain useful simplicity in this paper it will be necessary to regard only *Major Factors.* The importance, single and cumulative, of *Minor Factors* is well known. The inherent properties of the raw material (e. g., per cent of residual graphite in pig), the temperatures attended in the remelting processes, pouring temperature, etc., are examples of such minor, yet important, factors.

and tricky task. Since the advent of direct combustion methods for this determination, carbon determinations are more frequent and probably more accurate. More frequent correlation of carbon analyses with physical tests, and the wider use of the microscope by iron metallurgists, has led to clearer understanding of the relationships between structure and mechanical properties of cast iron.

Indeed we know now that the properties of the metal depend largely on the absolute and relative amounts of graphitic and cementitic carbon, and on their distribution and size—and that the silicon and total carbon content are the most important composition factors influencing these carbon formations. Therefore the present classification is based on the percentages of these variables, *carbon and silicon*, as shown in Table 1.[2]

By segregating irons into these (or even narrower) groupings, it is possible to make a far more systematic study of their properties. Such methods are utilized in studies on steel and nonferrous metals. For example, in studies of the 88-10-2 (gunmetal) bronze, investigators usually confine themselves pretty closely to this base composition—and as a result we find much valuable data on this *particular alloy*. If investigators were to tackle bronzes, including 88-10-2, 85-5-5-5, 80-10-10, etc., etc., as bronze, it would result in much confusion. Therefore, cast irons should be studied in groups, arranged in order of their composition.

Nearly all commercial cast irons will come within the forty groups listed. Some of the writer's data[3] on these groups are summarized in Table 5.

Cooling Rate Important

Composition and cooling rate are the major factors affecting the working properties of cast iron—further, the most important elements in composition are *carbon* and *silicon*. The *absolute* cooling rate depends on a number of factors—for example, *initial temperature* (which may or may not coincide with pouring tem-

[2] In order to attain greater coherence in the body of the paper many comments and explanations are included within the tables and footnotes. Therefore, detailed study of the tables, diagrams and footnotes will make many points more clear.

[3] It must be borne in mind that these results were attained in different foundries, on vastly different types of work, by different test engineers and chemists, often using different methods and equipment. Discrepancies have not been deleted and many of the results were attained under what may be termed routine conditions.

Table 1

CLASSIFICATION OF CAST IRONS ACCORDING TO SILICON AND CARBON CONTENT

Group No.	Per Cent Carbon	Per Cent Silicon	Carbon + 0.30 Silicon	Carbon + Silicon
1	Above 3.50	Above 2.50	4.25 up	6.00 up
2	" "	2.26—2.50	4.21 up	5.88 up A
3	" "	2.01—2.25	4.14 up A	5.63 up C
4	" "	1.76—2.00	4.06 up B	5.38 up E
5	" "	1.51—1.75	3.99 up C	5.13 up G
6	" "	1.26—1.50	3.91 up D	4.88 up I
7	" "	1.01—1.25	3.83 up E	4.63 up K
8	" "	.76—1.00	3.76 up F	4.88 up M
9	3.26—3.50	Above 2.50	4.13 up A	5.88 up A
10	" "	2.26—2.50	4.09 B	5.76 B
11	" "	2.01—2.25	4.02 C	5.51 D
12	" "	1.76—2.00	3.94 D	5.26 F
13	" "	1.51—1.75	3.87 E	5.01 H
14	" "	1.26—1.50	3.79 F	4.76 J
15	" "	1.01—1.25	3.71 G	4.51 L
16	" "	.76—1.00	3.64 H	4.26 N
17	3.01—3.25	Above 2.50	3.88 up D	5.63 up C
18	" "	2.26—2.50	3.84 E	5.51 D
19	" "	2.01—2.25	3.77 F	5.26 F
20	" "	1.76—2.00	3.69 G	5.01 H
21	" "	1.51—1.75	3.62 H	4.76 J
22	" "	1.26—1.50	3.54 I	4.51 L
23	" "	1.01—1.25	3.46 J	4.26 N
24	" "	.76—1.00	3.39 K	4.01 O
25	2.76—3.00	Above 2.50	3.63 up H	5.38 E
26	" "	2.26—2.50	3.59 H	5.26 F
27	" "	2.01—2.25	3.52 I	5.01 H
28	" "	1.76—2.00	3.44 J	4.76 J
29	" "	1.51—1.75	3.37 K	4.51 L
30	" "	1.26—1.50	3.29 L	4.26 N
31	" "	1.01—1.25	3.21 M	4.01 O
32	" "	.76—1.00	3.14 N	3.76 P
33	2.51—2.75	Above 2.50	3.38 up K	5.13 G
34	" "	2.26—2.50	3.34 K	5.01 H
35	" "	2.01—2.25	3.27 L	4.76 J
36	" "	1.76—2.00	3.19 M	4.51 L
37	" "	1.51—1.75	3.12 N	4.26 N
38	" "	1.26—1.50	3.04	4.01 O
39	" "	1.01—1.25	2.96	3.76 P
40	" "	.76—1.00	2.89	3.51

NOTES: Manganese on most foundry irons runs between 0.45 and 0.80, within which range no sub-classification seems necessary. Phosphorus subdivisions might be 0.0—0.15, 0.16—0.30, 0.31—0.50, 0.51—0.70, 0.71—1.00; this element influences the stiffness of the metal and also is a factor in its fluidity and hardness. At the present time, no logical subdivisions on sulfur content have occurred to the writer; perhaps the sulfur/manganese ratio will furnish a basis for further classification. Nickel and chromium have powerful influences on cast iron, and irons containing them exhibit somewhat different characteristics than "straight" silicon-carbon irons.

perature), *final temperature,* the *composition* of the alloy (including gas content as well as per cent metals and metalloids) (the preceding being reflected to some degree in the *specific heat*), the *speed of pouring,* the *volume* of the casting, the *area* exposed to cooling, the *heat conductivity* of the metal itself and of the mold material (core, green sand, dry sand, etc.), and all those forms of energy made apparent in *thermal arrests* (freeing of cementite and graphite; separation of steadite, allotropic modifications, austenite pearlite reaction, etc.) and like factors. The writer hopes to deal more completely with *absolute* cooling rates[4] in a subsequent paper.

For our present purpose it is sufficient and more simple to consider only *relative cooling rate.* Assuming relatively close initial temperatures, all final temperatures being room temperatures, and close values for specific heats, the relative cooling rates are roughly proportional to the ratio $\frac{\textit{volume}}{\textit{surface area}}$. This is a simple mathematical way of expressing a well known foundry fact—i. e., that the cooling rate is proportional to *section size.* Table 2 gives the relative cooling rates for a number of shapes. Expressed another way, the *heat* to be dissipated in cooling depends directly on the *volume* of metal, and the *rate* with which the heat can be abstracted depends on the *exposed area*—i. e., the surface.

Properties of Castings

Gray irons have been divided into a number of groups, according to composition in silicon and carbon and a method indicated for subdividing these composition groups according to the relative

[4] Cooling rate is not a straight line function. The factors mentioned above are still further complicated by the fact that "final" temperature is a very complicated phenomenon. For example, the mold is getting hot as the metal cools down. (Fig. 1.) Beside this we do not have uniform cooling over the cross sectional area of any section. In other words, the varying cooling gradients between conducting medium and casting on one hand, and between various layers of the casting on the other, plus the fact that the cooling rates are curve functions, make it impossible to express cooling rate from solidus to last reaction point in degrees per minute (or per second). However, the effect of even slight cooling gradients within castings are of great practical importance. Every foundryman has noticed the sharp "breaks" and "picture frame" effects found in some fractures. These indicate "critical gradients" and these critical points probably are quite sharply defined. The sharpness of the effects produced by these temperature critical gradients is greater in higher carbon irons. The lower carbon irons and nickel irons have less tendency to show such radical changes in structure due to what must be rather slight thermal gradients. Therefore these latter irons generally are more uniform in their physical properties from section to section of the same casting. The element silicon also has a very sharply defined "chemical critical gradient"—wherein a few points variation may mean either white or gray iron—see Fig. 2.

Table 2

COOLING RATES AND RELATIVE MODULI OF VARIOUS BARS

Diameter Inches	Length Cast Inches	Length Tested Inches	Cross Section Area	Surface Area Sq. Inches	Volume Cubic Inches	*Volume* / *Surface Area*	Relative Modulus of Rupture
0.500	21	18	0.196	33.4	4.12	0.1234	366.640
0.75	21	18	0.442	50.36	9.28	0.1843	108.623
0.875	21	18	0.601	58.9	12.6	0.2139	68.414
1.00	21	18	0.785	67.5	16.5	0.2444	45.831
1.20	21	18	1.131	81.4	23.8	0.2924	26.523
1.30	21	18	1.327	88.4	27.9	0.3156	20.860
1.40	21	18	1.539	95.4	32.3	0.3386	16.702
1.50	21	18	1.767	102.5	37.1	0.3620	13.579
2.00	21	18	3.142	138.2	66.0	0.4776	5.7288
2.20	21	18	3.801	152.7	79.8	0.5226	4.3042
2.50	21	18	4.909	174.8	103.1	0.5898	2.9332
3.00	21	18	7.069	212.1	148.4	0.6996	1.697
0.80	15	12	0.503	38.7	7.55	0.1951	59.672
1.00	15	12	0.785	48.7	11.8	0.2423	30.552
1.25	15	12	1.227	61.4	18.4	0.2997	15.666
1.50	15	12	1.767	74.2	26.5	0.3571	9.052
2.00	15	12	3.142	100.5	47.1	0.4686	3.819
3.00	15	12	7.069	155.5	106.0	0.6817	1.1316
4.00	15	12	12.57	213.6	188.6	0.8830	0.477
6.00	15	12	28.27	339.3	424.1	1.250	0.141
8.00	15	12	50.27	477.5	754.1	1.579	0.0596
Square B. & H.							
1.0×1.0	27	24	1.00	110.0	27.0	0.2455	36.00
2.0×1.0	27	24	2.00	166.0	54.0	0.3253	18.00
1.0×2.0	27	24	2.00	166.0	54.0	0.3253	9.00
¼×12×12	..	..	...	....	...	0.1200	....
½×12×12	..	..	...	....	...	0.2308	....
1×12×12	..	..	...	....	...	0.4286	....
2×24×24	..	..	...	....	...	0.8571	....
3×24×24	..	..	...	....	...	1.200	....
4×24×24	..	..	...	....	...	1.440	....

NOTES: Assuming same pouring temperature, like specific heats, and like liquid gas content, heat energy as cast of bars of given analysis is roughly proportional to *Volume.* Potential energy (total) also varies according to the allotropic modifications (delta, gamma, alpha) and that due to transformations like cementite—ferrite—graphite or austenite—pearlite.

Assuming same conductivity of mediums (mold) *Cooling Rate* is roughly proportional to the ratio $\dfrac{\textit{Volume}}{\textit{Surface Area}}$

$$\textit{Surface Area} = \pi D L_B + \pi \frac{D^2}{2} \qquad \textit{Volume} = \frac{\pi D^2}{4} L_B \ (L_B = \text{length as cast})$$

$$\textit{Modulus of Rupture} = \frac{8LS}{\pi D^3} \text{ or } \frac{2.546LS}{D^3} \text{ for round, } \frac{3LS}{2BH^2} \text{ for square.}$$

L = distance between knife edges, S = breaking load, D = diameter.

This formula is for elastic beams, and assumes center of gravity on geometric axis of bar. This is not true for cast iron, center of gravity varying as elastic limits in tension and compression are dissimilar. However, the modulus of rupture gives good comparisons.

The ratio of $\dfrac{\textit{volume}}{\textit{surface area}}$ plotted against bar diameter is almost a straight line for diameters up to three inches and "as cast" lengths of 15 inches or over. Thus $D \times 0.24$ = the ratio. Or the relative cooling rate is almost proportional to the diameter.

Plotting relation of diameter to relative modulus of rupture gives a curve of the hyperbolic type.

Table 3

	Robertson Shackles 0.505 Inch Bar Tensile Strength Lbs. per Sq. Inch	Regular Ball Joint 0.800 Inch Bar Tensile Strength Lbs. per Sq. Inch
1	14,000	15,657
2	23,500	24,937
3	22,300	21,519
4	20,500	25,131
5	27,000	33,860
6	32,500	34,575
7	20,500	24,248
8	39,125	38,860
9	42,375	42,910
10	34,150	35,380
11	37,450	35,380
Average	28,491	30,223

NOTES: Results on regular ball joints are averages, those on Robertson Shackles are single tests.

The 0.505 bar is naturally weaker than the 0.800 bar, so the lower result of the Robertson Shackles is not unexpected.

Table 4

SOME PROPERTIES OF CAST IRON*

GROUP I

(1) Chemical composition (elements by weight)
(2) Structural composition (microstructure, components by volume, distribution, etc.)
(3) Thermal properties (thermodynamic, time, pressure, temperature effects)
(4) Specific gravity (liquid, solid, etc.)
(5) Specific heat (over temperature range)
(6) Color (including emissivity when molten)
(7) Electrical and magnetic properties
(8) Changes of dimension (including dilatation, growth, contraction, shrinkage)
(9) Thermal conductivity
(10) Fluidity

GROUP II

(1) Tensile strength (including elasticity)
(2) Shear
(3) Compression
(4) Torsion
(5) Transverse and deflection (including modulus of rupture, resilience, etc.)
(6) Impact type tests (Charpy, Izod, etc.)
(7) Fatigue (reversal of stress—including also low temperature creep tests)
(8) Hardness tests (brinell, rockwell, sclerescope, scratch test, etc.)

GROUP III

(1) Machinability and finish
(2) Wear
(3) Corrosion resistance
(4) Heat treatments
(5) Influences due peculiarities of stock (pig iron, coke, etc.)
(6) Influences of melting medium, and other operations
(7) Influences of pouring temperatures, section size, etc.

*These properties are of interest at elevated temperatures as well as at room temperatures.

cooling rate. The next question is: *Can we determine the properties of the casting from the properties of the test bar?* If we cannot establish reasonable correlation of tests to the properties of the castings themselves, cast iron research is futile. It is the *casting* that the engineer designs, the manufacturer sells, and the customer buys. These men care little about the "quality of the iron in the ladle." They are concerned only with what they get, namely, the casting. However, it is possible to tell a great deal about the quality of the metal in the casting. Before citing direct data on this point, let us consider general experience and the logic of such an attempt.

(a) Many working properties of steel and other metals are regularly predicted from tests. Granting the limitations of tests and the difficulty of their exact interpretation, no one would deny that great progress has been made by use of tests and, in a general way, tests are used every day to determine properties of commercial metals.

(b) If in two or more cases exactly the same grade of material is accorded the same treatment, the altered materials will still be the same, one to another.

(c) Test bars are castings of certain specified shape and dimensions. If we pour castings and test bars all of the *same analysis and cooling rate,* we would expect to find similar metal in each. The problems here are: (1) to make test bars whose cooling rates are like those of the castings; and (2) to use common sense in making allowance for peculiarities in design and foundry practice—particularly those which may promote shrinkage or other defects and those which call for slow or fast pouring of castings.

(d) Indeed, the foundryman of wide experience can take an analysis and a result on one of the so-called arbitration test bars and many times predict pretty closely what the iron in the casting will be like.

Compares Bars and Castings

For purpose of demonstration, several grades of iron were chosen and an attempt made to check the relationship between castings and related test bars.[5]

[5] Talbot and Richart (A.S.T.M. Proceedings, Vol. 26, 1926) have presented an excellent paper on testing cast iron pipe, correlating tests on the whole pipe, samples from the pipe, and separate test bars.

Table 5

GENERAL SUMMARY

Group	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	Diameter Cast	Transverse Load	Deflection in Inches	Span in Inches	Transverse Modulus of Rupture	Tensile Strength Lbs. per Sq. Inch	Diameter Pulled in Inches	Shear Strength Lbs. per Sq. Inch	Diameter Sheared	Brinell 3000 kg.	Rockwell B	Scleroscope	Specific Gravity	Per Cent Steel	Melting Temperature	Number of Samples Tested
1	3.51	2.56	0.63*	0.29*	0.105*	0.15*	0.04*	1.20	1,844	0.314	18	48,908	18,795	0.800	.....	....	...	78*	..	....	Low	2775	9
1	3.50	2.62	...	...	....	...	...	1.20	1,834	0.294	18	48,731	.....	....	.....	....	...	..	..	....	Low	2775	7
2	Few available.																						
3 A	3.52	2.17	0.60	0.32	0.086	...	...	0.50	195	0.710	18	71,495	32,317	0.375	41,550	0.358	...	96.5	30	7.181	5	2750	5
3 B	3.52	2.17	0.60	0.32	0.086	...	...	0.75	560	0.500	18	60,829	30,243	0.505	38,800	0.505	180	90.5	30	7.112	5	2750	6
3 C	3.52	2.17	0.60	0.32	0.086	...	...	1.00	1,191	0.275	18	51,289	22,205	0.505	32,850	0.505	162	88.0	32	7.116	5	2750	4
3 D	3.57	2.19	0.63	0.30	0.061	...	...	1.20	1,703	0.280	18	45,169	20,082	0.686	28,937	0.505	159	..	..	....	5	2750	6
3 E	3.52	2.17	0.60	0.32	0.086	...	...	2.00	7,170	0.165	18	41,075	13,485	0.800	24,325	0.505	112	..	..	7.087	5	2750	3
3 F	3.52	2.17	0.60	0.32	0.086	...	...	3.00	18,173	0.118	18	30,840	11,561	0.800	20,500	0.505	94	..	..	6.972	5	2750	3
4 A	3.50	1.71	0.48	0.36	0.087	...	...	0.50	231	0.728	18	84,694	41,705	0.319	43,925	0.358	...	96	31	7.174	10	2700	5
4 B	3.50	1.71	0.48	0.36	0.087	...	...	0.75	646	0.567	18	70,170	34,718	0.505	43,870	0.505	189	93	30	7.186	10	2700	5
4 C	3.50	1.71	0.48	0.36	0.087	...	...	1.00	1,349	0.348	18	61,826	29,885	0.686	39,382	0.505	183	89	30	7.185	10	2700	4
4 D	3.52	1.73	0.46	0.35	0.073	...	...	1.20	....	....	18	.....	25,478	0.686	.....	....	...	..	..	....	10	2700	2
4 E	3.53	1.75	0.66	0.41	....	...	...	1.25	3,475	0.150	12	54,439	.....	....	.....	....	...	..	..	....	10	2700	8
4 F	3.65	1.88	0.68	0.60	0.107	...	...	1.25	2,988	0.089	12	.....	.....	....	.....	....	...	..	..	....	0	2650	4
4 G	3.65	1.83	0.58	0.45	0.121	...	...	1.25	3,093	0.127	12	.....	24,020*	0.800	.....	....	...	..	..	....	0	2650	3
4 H	3.61	1.84	0.46	0.51	0.122	...	...	1.25	3,520	0.115	12	.....	.....	....	.....	....	...	..	..	....	0	2650	4
4 I	3.56	1.87	0.63	0.56	0.095	...	...	1.25	3,333	0.097	12	.....	.....	....	.....	....	...	..	..	....	0	2650	3
4 J	3.62	1.78	0.61	0.48	0.115	...	...	1.25	3,230	0.105	12	.....	.....	....	.....	....	...	..	..	....	0	2650	4
4 K	3.57	1.84	0.54	0.45	0.125	...	...	1.25	3,253	0.110	12	.....	.....	....	.....	....	...	..	..	....	0	2650	9
4 L	3.54	1.81	0.56	0.38	0.137	...	...	1.25	3,207	0.115	12	.....	22,945	0.800	.....	....	177	..	..	....	0	2650	3
†4 M	3.59	1.83	0.58	0.49	0.118	...	...	1.25	3,268	0.108	12	51,196	23,214	0.800	.....	....	177	..	..	....	0	2650	30
4	3.59	1.81	0.66	0.37	0.099	...	...	2.00	10,635	0.083	12	40,615	16,240	0.800	.....	....	...	..	..	....	0	2650	11
4	3.62	1.78	0.66	0.40	0.088	...	...	2.00	10,904	0.082	12	41,642	.....	....	.....	....	...	..	..	....	0	2650	5
4	3.75	1.74	0.65	0.35	0.107	...	...	2.00	10,315	0.080	12	39,395	17,260	0.800	.....	....	...	..	..	....	0	2600	1
4	3.50	1.71	0.48	0.36	0.087	...	...	2.05	9,157	0.203	18	48,712	18,455	0.800	26,895	0.505	152	..	..	7.114	10	2750	..
4	3.50	1.71	0.48	0.36	0.087	...	...	3.00	25,288	0.143	18	42,914	15,056	0.800	23,456	0.505	134	..	..	7.054	10	2750	..
4	3.50§	1.77	0.48	0.67	0.116	...	...	4.00	....	....	12	31,332‖	14,253	0.800	.....	....	105	..	..	....	0	2650	..
4	3.50§	1.72	0.52	0.38	0.074	...	...	8.00	....	....	12	.....	14,520	0.800	.....	....	...	..	..	....	0	2650	..
5	3.72	1.67	0.62	0.41	0.126	...	...	1.25	3,045	0.109	12	47,703	.....	....	.....	....	...	..	..	....	0	2650	4
5	3.51	1.65	0.66	0.44	0.126	...	...	1.25	3,419	0.112	12	53,512	21,365‡	0.800	.....	....	...	..	..	....	0	2650	17
5	3.58	1.69	0.63	0.36	0.098	...	...	2.00	10,613	0.087	12	40,531	.....	....	.....	....	...	..	..	....	0	2650	6
5	3.57	1.63	0.64	0.30	0.108	...	...	2.00	13,482	0.089	12	51,488	18,180‡	0.800	.....	....	...	..	..	....	10	2650	5
5	3.54	1.55	0.64	0.28	0.118	...	...	2.00	13,621	0.095	12	52,019	.....	....	.....	....	...	..	..	....	15	2650	6

(Continued on next page)

Table 5

GENERAL SUMMARY

(Continued)

Group	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	Diameter Cast	Transverse Load	Deflection in Inches	Span in Inches	Transverse Modulus of Rupture	Tensile Strength Lbs. per Sq. Inch	Diameter Pulled in Inches	Shear Strength Lbs. per Sq. Inch	Diameter Sheared	Brinell 3000 kg.	Rockwell B	Scleroscope	Specific Gravity	Per Cent Steel	Melting Temperature	Number of Samples Tested
6	3.57	1.36	0.56	0.26	0.111	...	...	1.00	....	....	12	.....	31,623	0.686	.....	....	185	..	..	....	20	2650	3
6	3.57	1.45	0.59	0.30	0.120	...	...	1.25	3,925	0.127	12	61,489	30,165	0.800	.....	....	...	..	..	....	15	2650	2
6	3.55	1.43	0.62	0.26	0.136	...	...	2.00	13,520	0.095	12	51,633	.....	....	.....	....	...	..	..	....	15	2650	5
7	3.51	1.24	0.60	0.29	0.114	...	...	1.00	....	....	12	.....	31,590	0.686	.....	....	207	..	..	....	20	2650	2
7	3.51	1.24	0.67	0.31	0.151	...	...	1.25	4,550	....	12	71,280	.....	....	.....	....	...	..	..	....	20	2650	1
8	Few available.																						
9 A	3.34	2.86	0.58	0.28	....	0.15	.02-.04	1.20	1,988	0.289	18	52,728	21,150	0.800	.....	....	...	..	..	....	0	2750	5
9 B	3.33	2.62	...	...	....	Traces		1.20	2,380	0.331	18	63,125	27,747	0.800	.....	....	...	..	..	....	10	2800	4
10	3.35	2.35	0.57	0.19	0.114	1.29	0.06*	1.20	2,609	0.307	18	69,199	33,074	0.800	.....	....	...	..	..	....	25	2800	4
11	Few available.																						
12	3.29	1.76	0.61	0.16	0.090*	1.26	0.06*	0.051	208	0.526	18	71,885	41,601	as cast	.....	....	...	97	..	7.3116	25	2800	8
12	3.29	1.76	0.61	0.16	0.090*	1.26	0.06*	0.077*	....	....	18	.....	37,415	as cast	47,175	0.505	205	96	..	7.2802	25	2800	10
12	3.30	1.80	...	...	....	1.25*	0.06*	0.075	....	....	18	.....	37,083	0.505	.....	....	...	95	..	....	25	2800	3
12	3.32	1.87	...	0.20	0.095	1.27	0.06*	0.120	2,638	0.313	18	69,978	33,004	0.800	.....	....	...	..	..	....	25	2800	16
12	3.29	1.76	0.61	0.16	0.090*	1.26	0.06*	0.146	4,788	....	18	70,527	31,468	0.800	.....	....	209	96	..	7.271	25	2800	8
12	3.29	1.76	0.61	0.16	0.090*	1.26	0.06*	0.195	11,100	....	18	68,598	26,880	0.800	38,425	0.505	196	94	..	7.282	25	2800	6
12	3.29	1.76	0.61	0.16	0.090*	1.26	0.06*	0.297	35,500	....	18	62,090	24,815	0.800	35,963	0.505	179	89	..	7.257	25	2800	6
13	3.26	1.68	0.46	0.33	0.083	...	...	0.050	233	0.655	18	85,427	43,971	0.312	47,550	0.358	...	96	20	7.214	20	2850	5
13	3.24	1.68	0.46	0.33	0.083	...	...	0.075	661	0.507	18	71,719	38,860	0.505	46,554	0.505	194	90	23	7.231	20	2850	6
13	3.31	1.68	0.46	0.33	0.083	...	...	1.00	1,559	0.347	18	71,494	34,575	0.505	44,020	0.505	198	91	28	7.087	20	2850	4
13	3.37	1.61	0.46	0.33	0.063	...	...	1.20	....	....	..	.....	34,457	0.686	.....	....	...	..	..	....	..	2850	5
13	3.39	1.58	0.62	0.34	0.140	...	...	1.25	4,160	0.127	12	65,171	30,174	0.800	.....	....	187	..	..	....	10	2650	5
13	3.38	1.56	0.64	0.30	0.119	...	...	2.00	14,737	0.087	12	56,281	26,860	0.800	.....	....	...	..	..	....	15	2650	17
13	3.39	1.65	0.67	0.28	0.112	...	...	2.00	14,284	0.098	12	53,550	.....	....	.....	....	...	..	..	....	10	2650	13
13	3.24	1.68	0.46	0.33	0.083	...	...	2.04	10,655	0.202	18	57,515	24,248	0.800	33,960	0.505	173	84	29	7.140	20	2850	3
13	3.24	1.68	0.46	0.33	0.083	...	...	3.00	31,970	0.155	18	53,973	19,515	0.800	31,525	0.505	156	80	30	7.075	20	2850	3
13	3.35	1.54	0.42	0.54	0.170	...	...	4.00	2,815‖	0.140	12	.....	21,350	0.800	.....	....	128	..	..	....	15	2650	2
14	3.42	1.35	0.56	0.29	0.136	...	...	1.00	....	....	12	.....	36,583	0.800	.....	....	204	..	..	....	20	2650	11
14	3.45	1.41	0.56	0.28	0.133	...	...	1.00	....	....	12	.....	37,013	0.800	.....	....	200	..	..	....	15	2650	3
14	3.35	1.32	0.62	0.31	0.117	...	...	1.25	4,430	0.124	12	.....	34,892	0.800	.....	....	196	..	..	....	20	2650	5
14	3.36	1.36	0.46	0.50	0.095	...	...	1.25	4,025	0.104	12	.....	.....	....	.....	....	...	..	..	....	20	2650	6
14	3.37	1.34	0.64	0.38	0.115	...	...	1.25	4,253	0.112	12	.....	.....	....	.....	....	...	..	..	....	20	2650	8
14	3.37	1.36	0.56	0.35	0.121	...	...	1.25	4,251	0.124	12	.....	.....	....	.....	....	...	..	..	....	20	2650	12

(Concluded on next page)

Table 5
GENERAL SUMMARY
(Concluded)

Group	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	Diameter Cast	Transverse Load	Deflection in Inches	Span in Inches	Transverse Modulus of Rupture	Tensile Strength Lbs. per Sq. Inch	Diameter Pulled in Inches	Shear Strength Lbs. per Sq. Inch	Diameter Sheared	Brinell 3000 kg.	Rockwell B	Scleroscope	Specific Gravity	Per Cent Steel	Melting Temperature	Number of Samples Tested
14	3.40	1.45	0.59	0.30	0.133	...	...	1.25	4,008‖	0.132	12	65,703‡	31,126	0.800	...	...	...	..	..	...	20	2650	9
14	3.33	1.36¶	0.61	0.28	0.127	...	...	2.00	15,744‖	0.087	12	60,126	...	...	...	...	...	..	.	...	20	2650	8
14	3.43	1.32¶	0.61	0.28	0.119	...	...	2.00	15,240‖	0.095	12	...	...	...	...	...	...	..	..	...	20	2650	8
14	3.33	1.44¶	0.63	0.27	0.118	...	...	2.00	15,660‖	0.095	12	...	...	...	...	...	...	..	..	...	15	2650	7
14	3.43	1.43¶	0.59	0.29	0.118	...	...	2.00	14,385‖	0.082	12	58,266‡	28,000‡	...	...	...	...	..	..	...	15	2650	7
15	3.39	1.14	0.55	0.25	0.119	...	...	1.25	4,436	0.135	12	69,495	33,167	0.800	...	...	205	..	..	...	20	2650	4
15	3.28	1.15	...	...	...	...	...	2.00	17,400	0.095	12	66,450	...	...	...	...	...	..	..	...	20	2650	1
16	None available.																						
17	None available.																						
18	3.16	2.40	0.57	0.27	0.047	...	...	0.50	...	...	18	...	41,887	0.320	47,326	0.358	...	100	..	...	8	2700	2
18	3.16	2.40	0.57	0.27	0.047	...	...	1.00	1,692	0.350	18	77,545	35,380	0.686	42,755	0.505	183	95	..	...	8	2700	2
18	3.16	2.40	0.57	0.27	0.047	...	...	2.00	10,733	0.187	18	61,490	21,060	0.800	29,700	0.505	146	79	..	...	8	2700	2
18	3.16	2.40	0.57	0.27	0.047	...	...	3.00	27,085	0.149	18	45,965	15,903	0.800	24,900	0.505	99	60	..	...	8	2700	2
19	3.12	2.06	0.61	0.31	0.047	0.40	...	1.00	1,805	0.315	18	82,725	40,162	0.686	50,050	0.505	235	96	..	...	Yes	2750	2
19	3.12	2.06	0.61	0.31	0.047	0.40	...	1.20	...	...	18	...	39,068	0.686	47,800	0.505	202	95	..	...	Yes	2750	2
19	3.12	2.06	0.61	0.31	0.047	0.40	...	2.00	13,351	0.189	18	76,483	33,860	0.800	42,500	0.505	187	90	..	...	Yes	2750	3
19	3.12	2.06	0.61	0.31	0.047	0.40	...	3.00	38,240	0.150	18	64,895	25,803	0.800	37,425	0.505	159	87	..	...	Yes	2750	3
19	3.07	2.04	0.54	0.24	0.057	0.45	...	0.50	...	...	18	...	40,013	0.320	...	...	...	97	..	...	Yes	2750	2
19	3.07	2.04	0.54	0.24	0.057	0.45	...	1.00	1,735	0.364	18	...	37,443	0.686	44,150	0.505	210	95	..	...	Yes	2750	3
19	3,07	2.04	0.54	0.24	0.057	0.45	...	1.20	...	...	18	...	32,596	0.686	40,550	0.505	207	95	..	...	Yes	2750	2
19	3.07	2.04	0.54	0.24	0.057	0.45	...	2.00	11,178	0.197	18	...	25,131	0.800	32,975	0.505	166	84	..	...	Yes	2750	3
19	3.07	2.04	0.54	0.24	0.057	0.45	...	3.00	35,155	0.164	18	...	21,519	0.800	31,925	0.505	161	83	..	...	Yes	2750	2
19	2.94	1.92	0.57	0.27	0.058	0.51	...	1.00	1,722	0.311	18	78,921	39,136	0.686	49,125	0.505	215	96	..	...	Yes	2750	3
19	2.94	1.92	0.57	0.27	0.058	0.51	...	1.20	...	...	18	...	40,187	0.686	47,125	0.505	207	93	..	...	Yes	2750	2
19	2.94	1.92	0.57	0.27	0.058	0.51	...	2.00	12,901	0.193	18	73,907	29,617	0.800	41,200	0.505	192	91	..	...	Yes	2750	3
19	2.94	1.92	0.57	0.27	0.058	0.51	...	3.00	39,028	0.160	18	66,231	24,937	0.800	36,450	0.505	181	88	..	...	Yes	2750	3
20	None available.																						
21	3.24	1.71	0.78	0.21	0.117	...	...	2.00	16,105	0.105	12	61,502	...	...	...	...	...	..	..	...	15	2650	2
22	3.16	1.35	0.49	0.37	0.116	...	...	1.25	4,297	0.118	12	...	40,510	0.800	...	...	212	..	..	...	25	2650	17
23	3.16	1.17	0.56	0.32	0.148	...	...	2.00	17,580	0.090	12	...	27,360	0.800	...	...	196	..	..	...	25	2650	1
24	None available.																						
25, etc.	Only two groups available, so omitted from Tables.																						

Total Samples 438

*Only a few, or vary widely. †Weighed average of items F to L, inclusive. §Calculated. ‖On 12 inch by 1.25 inch bar from center of 4 inch bar.
¶Average of four items.

Table 6

TESTS ON BARS—GROUPED BY DIAMETERS

	Carbon	Silicon	Manganese	Phos.	Sulphur	Nickel	Chromium	Transverse Modulus of Rupture	Deflection in Inches	Tensile Strength Lbs./Sq. In.	Shear Strength Lbs./Sq. In.	Brinell Hardness No.	Si+C	C+0.3 Si
								Tests on Bars 1.0" Diameter						
A	3.52	2.17	0.60	0.32	0.086	...	...	1,191	0.275	22,205	32,850	162	5.69*	4.17
A	3.50	1.71	0.48	0.36	0.087	...	...	1,349	0.348	29,885	39,285	183	5.21†	4.01
A	3.57	1.36	0.56	0.26	0.111	...	...	....	....	31,623	.....	185	4.93†	3.98
A	3.51	1.24	0.60	0.29	0.114	...	...	....	....	31,590*	.....	207	4.75†	3.88
B	3.31	1.68	0.46	0.33	0.083	...	...	1,559	0.347	34,575	44,020	198	4.99†	3.81
B	3.42	1.35	0.56	0.29	0.136	...	...	....	....	36,583	.....	204	4.77†	3.82
C	3.16	2.40	0.57	0.27	0.047	...	...	1,692	0.350	35,380	42,755	183	5.46†	3.88
C	3.12	2.06	0.61	0.31	0.047	0.40	...	1,805	0.315	40,162	50,050	235	5.18†	3.74
								Tests on Bars 1.20" Diameter						
A	3.51	2.56	0.63	0.29	0.105	0.15	0.04	1,844*	0.314	18,795	.....	...	6.07*	4.27
A	3.57	2.19	0.63	0.30	0.061	...	...	1,703	0.280	20,082	28,937	159	5.76*	4.23
A	3.52	1.73	0.46	0.35	0.073	...	...	....	....	25,478	.....	...	5.25†	4.04
B	3.34	2.86	0.58	0.28	....	0.15	0.03	1,988	0.289	21,150	.....	...	6.20*	4.20
B	3.33	2.62	...	...	....	traces	traces	2,380	0.331	27,747	.....	...	5.95†	4.11
B	3.35	2.35	0.57	0.19	0.114	1.29	0.06	2,609	0.307	33,074	.....	...	5.70†	4.06
B	3.32	1.87	...	0.20	0.095	1.27	0.06	2,638	0.313	33,009	.....	...	5.19†	3.88
B	3.37	1.61	0.46	0.33	0.063	...	...	....	....	34,457	.....	...	4.98†	3.85
C	3.12	2.06	0.61	0.31	0.047	...	...	....	....	39,068	47,800	202	5.18†	3.73
								Tests on Bars 1.25" Diameter						
A	3.59	1.83	0.58	0.49	0.118	...	...	3,268	0.108	23,214	.....	177	5.42*	4.14
A	3.72	1.67	0.64	0.41	0.126	...	...	3,045	0.109	.....	.....	...	5.39*	...
A	3.51	1.65	0.66	0.44	0.126	...	...	3,419	0.112	.....	.....	...	5.16*	...
A	3.57	1.45	0.59	0.30	0.120	...	...	3,925	0.127	30,165	.....	...	5.02†	4.00
A	3.51	1.24	0.67	0.31	0.151	...	...	4,550	....	.....	.....	...	4.75†	...
B	3.39	1.58	0.62	0.34	0.140	...	...	4,160	0.127	30,174	.....	187	4.97†	3.86
B	3.35	1.32	0.62	0.31	0.117	...	...	4,430	0.124	34,892	.....	196	4.67†	3.74
B	3.39	1.14	0.55	0.25	0.119	...	...	4,436	0.135	33,167	.....	205	4.53†	3.73
C	3.16	1.35	0.49	0.37	0.116	...	...	4,297	0.118	40,510	.....	212	4.51†	3.56
								Tests on Bars 2.00" Diameter						
A	3.52	2.17	0.60	0.32	0.086	...	...	41,075	....	13,485	24,325	112	5.69‡	4.17
A	3.62	1.78	0.66	0.40	0.088	...	...	41,462	....	16,750	.....	...	5.40*	4.17
A	3.50	1.71	0.48	0.36	0.087	...	...	48,712	....	18,455	26,895	152	5.21†	4.01
A	3.58	1.69	0.63	0.36	0.098	...	...	40,531	....	.....	.....	...	5.27*	4.09
A	3.57	1.63	0.64	0.30	0.108	...	...	51,488	....	18,180*	.....	...	5.20†	4.06
A	3.55	1.43	0.62	0.26	0.136	...	...	51,633	....	.....	.....	...	4.98†	3.98
B	3.29	1.76	0.61	0.16	0.090	1.26	0.06	68,598	....	26,880	38,425	196	5.05†	3.82
B	3.38	1.56	0.64	0.30	0.119	...	...	56,281	....	26,860	.....	...	4.94†	3.85
B	3.33	1.36	0.61	0.28	0.127	...	...	60,126	....	.....	.....	...	4.69†	3.74
B	3.28	1.15	...	...	....	...	...	66,450	....	.....	.....	...	4.43†	3.63
C	3.16	2.40	0.57	0.27	0.047	...	...	61,490	....	21,060	29,700	146	5.46†	3.88
C	3.12	2.06	0.61	0.31	0.047	0.40	...	76,483	....	33,860	42,500	187	5.18†	3.72
C	3.24	1.71	0.78	0.21	0.117	...	...	61,502	....	.....	.....	...	4.95†	3.75
C	3.16	1.17	0.56	0.32	0.148	...	...	67,130§	....	27,360§	.....	196	4.33†	3.51
D	2.65	1.75	0.62	0.28	0.060	1.15	...	83,330	....	39,340	45,765	223	4.40†	3.17

*No steel. †Semi-steel. ‡Steel under 5%. §Few samples.

Case 1: A 125 pound casting of uniform section was broken up and a piece cut out as shown in Fig. 3. The metal section of the casting was 1½ inches, and the analysis carbon 3.23, silicon 1.65. By calculation the $\frac{\textit{volume}}{\textit{surface area}}$ relationship was found to correspond quite closely to that of the 3.0 inch by 18 inch test bar. The analysis is that of group 13, Tables 1 and 5, and the iron was melted under the same conditions as that of the 3.0 inch by 18 inch bar of group 13, Table 5. The shear tests of the casting (sound sections) averaged 31,345 lbs. per sq. in. This corresponds to 31,525 lbs. per sq. in., the shear on the 3.0 inch by 18 inch bar given in group 13. Fig. 4 shows the straight line relationship between shear and tensile. Therefore we would be safe predicting a tensile around 20,000 lbs. per sq. in. The fracture of center of casting and center of bar were quite similar.

Case 2: In a somewhat more detailed study, the casting of design shown in Fig. 5 was thoroughly probed. We find the $\frac{\textit{volume}}{\textit{surface area}}$ of this casting (overall) is 0.61, corresponding approximately with test bar 2.4 inches by 18 inches. However, the casting is not uniform in section and allowance should be made for this fact. Beside, this was a scrap casting, due to blowholes in portions indicated. The analysis shows carbon 2.93, silicon 2.01, corresponding with group 27 or 28. A detailed list of the tests accompanies the diagram:

Tensile—T1	(35,507)	T—2—	39,265
Shear —1B	(41,875)	1—C—	45,946
—2B	(44,652)	2—C—	45,650
		3—C—	46,418

Brinell, edge, Average 203
rib, 195

Tensile T2 is slightly higher than T1, the latter being in the heavier portion of the rib. Shears 1B and 2B are close to T1, their average 43,263 lbs. per sq. in. transferred to tensile in shear-tensile chart, Fig. 4, being about 35,000 lbs. per sq. in.

(Compare this to 35,507 of T1.) The average of 1, 2 and 3C, 46,005 lbs. per sq. in., corresponds to a tensile of about 38,000 lbs. per sq. in. (Fig. 4). This is comparable to 39,265 lbs. per sq. in. of T2. Taking T1 and T2 average (37,368 lbs. per sq. in.) as representative of the casting, whose relative cooling rate approximates that of a 2.4 inch bar, we take the value 37,800 per sq. in. from the writer's data. This is a good check when one considers that the tensiles T1 and T2 were taken from a section subject to some shrinkage. The brinell's (196-203) when compared with the chart, Fig. 6, show that these check up with the tensile within the limitations of the brinell correlation.

Case 3: A fairly large casting, some 730 lbs., and of a quite uniform section of 1$\frac{13}{16}$, was selected. Its analysis is carbon 3.23, silicon 1.58, manganese 0.48, sulphur 0.056, phosphorus 0.39, nickel none. A chunk was broken out with the drop hammer. Tensiles A and D are 27,919, and 28,946 lbs. per sq. in. respectively (average 28,433 lbs. per sq. in.). Shears B and C are 37,150 and 37,575 lbs. per sq. in. respectively (average 37,362 lbs. per sq. in.). The ratio $\frac{volume}{surface\ area}$ of this casting is close to that of a 2¾ inch test bar. This section, from its place in the mold, had a good chance to cool, as metal in this part of the casting was the first from the ladle, ran over a core, and had to travel 28 inches before reaching the chunk broken out for test. The shear tensile ratio (37,362 to 28,433) checks well. However, the tensile is higher (28,433 against 22,500), than might be expected. This in all probability is due to the slow pouring rate and distance of travel of the metal.

Case 4: A 700 pound casting of fairly uniform cross section about 1 inch to 1½ inch as cast. Analysis, silicon 1.61, carbon 3.28. This comes in group 13, close to group 21. Relation of $\frac{volume}{surface\ area}$ corresponds closely with that of a 2 inch diameter test bar. From tests from iron made under like conditions but not in the same heat, we find:

	Casting	*Test Bars*
Tensile	1—26,840	A—25,825
	2—29,200	B—24,235
	3—30,500	
Shear	1—38,965	A—33,960
	2—42,004	
	3—40,435	
Brinell	1— 163	Average 172
	2— 174	

Here we have a good correlation, quite on the conservative side in so far as predictions upon the physical properties are concerned. As in the preceding case, the metal flow was choked down fairly well, and the distance of flow from gate to spots tested quite far. Beside this casting ran some 10 points carbon lower than the test bars.

Case 5: A 325 pound casting section about ¾″ as cast. Analysis silicon 2.42, carbon 3.22, therefore in group 18. Relative cooling rate approximates that of a 1½″ test bar. Tests show as follows:

	Casting	*Test bar interpolated from Chart*
Tensile	1—27,055	Tensile about 26,000
Shear	1—40,299	Shear about 37,000
	2—35,700	
	3—39,275	
	4—39,300	
Brinell	1— 179	Brinell about 180
	2— 174	

This, of course, is quite close.

Part 2

Remarks on Testing

Once having classified cast iron into various groups and subdivisions (according to *composition* and *cooling rate*), and having furnished data to show that there are relationships between

some properties of castings and of test bars of corresponding cooling rate and composition, we can begin the further study of some of the properties of cast iron. In case of a research association, it is possible to take a given group of irons and to study them very thoroughly—whereas no manufacturer is likely to be much interested in properties which have no bearing to his own problems. (See Table 4.)

Interpretation of Test Results

Before considering the tests on bars (Tables 5 and 6 and Figs. 10 to 21), it is well to consider some of the peculiarities inherent in the methods of testing. These characteristics of the various test methods must be taken into account when attempting to interpret the test results in a practical manner.

Analytical methods are pretty well standardized, and results on the usual elements may be considered dependable. The accurate determination for graphitic carbon involves extremely careful sampling, and results on this have been deliberately omitted from this paper until further check analyses can be made.

Structural composition is very important and the writer hopes to give fairly complete data along this line in a subsequent paper. The graphite carbon[6] is very important—perhaps the most important structural component influencing many properties.

The changes attending variation in cooling rates within castings afford real problems for co-operation research.

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[6] Graphite in gray iron is regular graphitic carbon, with the characteristic crystal structure and other properties of this form of carbon.

It occurs in gray iron in flakes, more or less curved and pencil-like in form, and varying widely in size.

The flakes consist largely of graphite, probably inmeshed in a ferritic network, and sometimes containing sulphide globules. For this latter reason sulphur prints of gray iron are likely to reveal the general graphite structure rather than the true sulphide distribution. The flakes often occur in characteristic groupings. These groupings depend largely on the *position* of the alloy in the iron-carbon-silicon diagram, and on the *cooling rate* of the casting.*

The *fracture* of gray iron follows the graphite flakes very closely since these flakes are the weakest part of the metal structure. Therefore the greater the *percentage* of these flakes, other things equal, the less the strength of the iron. The *specific gravity* of the flakes is much less than that of the matrix, therefore they are more effective than their percentage by weight would indicate.

Large coarse flakes are greater weakeners than are small flakes. Their presence indicates *large grain size* of all structures in the alloy, and this coarse structure makes for weakening of every part.

The distribution also is a factor in the strength of the iron, sometimes upsetting conclusions that might be reached from mere consideration of individual flake size.

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*Bolton, J. W., *Some Graphite Formations in Cast Iron*, *Trans.* A. F. A., Vol. 35, pp. 386-404 (1927).

We have heard for many years that the tensile test on cast iron is unreliable as cast iron is a rather inelastic material and any deviation from a straight pull would set up transverse stresses, and lead to erroneously low tensile results.[7]

The writer believes that carefully conducted tensile tests, made on reasonably aligned equipment, will give useful results.[8] However, the use of an axial loading device, such as the Robertson shackels, should be employed wherever possible.

The very limited use of tensile tests by foundrymen is unfortunate. The transverse test on the so-called arbitration bar is one not familiar to most designing engineers, and is not easily transferred into useful engineering terms. General tensile transverse ratios are inaccurate and of very limited usefulness.[9] The wider use of tensile tests by foundries deserves encouragement.

In general, the tensile results on castings may tend to run higher than on circular bars of similar relative cooling rate—because the actual distance from skin to center is less in the castings. This, and the fact that many castings are poured more slowly than the corresponding bars constitute two of the greatest difficulties in exact correlation of test bar to casting.

The uniformity test has a useful function in the interpretation of tensile and transverse tests. The methods of conducting uniformity tests is included in the notes to Fig. 8. Some investigators have published formulæ for conversion of brinell hardness numbers to tensile strength. Within narrow ranges of composi-

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[7] This opinion appears reasonable, inasmuch as so many cast iron tensile bars break at the fillet. However, the writer has noticed that little if any higher results may be obtained (on groups of bars of like metal) from the center breaking bars. Recently the Lunkenheimer physical laboratory tried out the differences between bars truly axially loaded and those pulled carefully in ordinary ball joint grips. The results are shown in Table 3.

[8] Nearly all the results given in the tables here were obtained with ordinary tensile equipment. This may explain some discrepancies, but the writer feels that all the average results are reasonably accurate.

[9] An unfortunate thing about the tensile test is that it is impractical to pull bars of large cross sectional area. On the three inch bars, for example, we have cut tensile bars, 0.800 inch diameter from the center. Obviously, this is the weakest portion of the cast bar and the tensile results are lower than the probable average strength of the piece. This deviation in strength from outside to center of the bar is more apparent in the higher carbon irons. The effect is obvious on close study of other tests. The variation or break in grain has been mentioned previously. The drop off in strength in transverse modulus of rupture is not as rapid as the drop in tensile pull (see charts for various groups). The brinell or rockwell tests across the bar show variations from outside to center. This effect is shown in the rockwell uniformity test illustrated in Fig. 8. It is apparent, too, in correlation tests of bars to castings.

tion there is a quite constant relationship. The writer doubts the practicability of any simple general formula for all grades of iron. As may be seen from Fig. 6, while there is a general relationship, individual variations are so large that the uselessness of any simple general formula is apparent.[10]

Machinability: Machinability is a relative term only. Two factors influence machinability of gray iron. These are strength and abrasiveness. (c.f. J. W. Bolton—Machinery—March, 1925.) High production schedules make it imperative that the metal be of high machinability. To meet this demand some foundrymen have gone to weaker and weaker irons. This tends toward lowering the service quality of the material. Increased strength undoubtedly increases tool resistance and promotes tendency toward chatter. The increased heat generated and the vibration (which, although hardly perceptible, result in many blows on the cutting portion of the tool), cut down the ultimate machine rates. Phosphorus formations and certain other structural forms increase the abrasive wear on the tool.

Heat Treatment: Heat treatment of gray irons has been very vigorously advocated. Within limited ranges certain treatments prove useful. Normalizing lowers chances of casting strains. Annealing produces very soft and machinable metal of lowered strength. Quenching and tempering operations are of limited usefulness, although valuable for some applications.

Corrosion: It is the writer's experience that under laboratory conditions, high strength irons corrode and are dissolved away quite as readily as weak metal. However, close grained irons undoubtedly give much better service in the field. The reasons for this are two. First, that corroding fluids *penetrate* the pores of the open grained metal quite readily—hence it is more subject to internal corrosion. Open irons pit and spall off more readily. Close irons resist wear better and the products of corrosion are not so readily removed.

Wear Resistance: Close grained irons usually resist wear better. Tests run without lubrication indicate that the harder

[10] The fundamental reason for this is that the graphite flakes possess little tensility, yet are relatively hard to compress when held in a rigid matrix.

irons resist wear best. Statements are made that soft irons do very well. Upon investigation it may be found that such opinions are based upon comparisons where the samples or parts were lubricated.

Rigidity: One of the most useful properties of cast iron is its rigidity. This property is related to the amount of stress required to produce unit deformation, or the modulus of elasticity. As a matter of fact, the modulus of elasticity of cast iron is not a constant, but varies both for different irons, and at different points on the stress-strain diagram of any given iron.[11] This applies in both tensile and transverse testing. (See Figs. 12 and 13A, B and C.)

Strength at Elevated Temperatures: The work of MacPherran and Harper on strength of iron at elevated temperatures has stood the test of time. Some tests on various grades of iron are shown in Fig. 14.

Part III

Discussion of Data

Space does not permit a detailed analysis of the data, of Tables 5 and 6, so that attention will be called to a few salient points only.

In Fig. 15a tensility is plotted against the $\frac{\textit{volume}}{\textit{surface area}}$ ratio. Curves are given covering some groups shown in Table 5. These curves are typical segments of the qualitative diagram advanced by the writer. (A. F. A. Exchange Paper to Belgium—1925). The writer hopes, in the future, to check these curves against results obtained by other investigators. *If it were possible to substitute actual for relative cooling rates and to subdivide*

[11] The writer has pointed out (Trans. A. F. A. Vol. 32, Part 1, and previous articles) that the fracture of gray iron is progressive, proceeding from point to point along the graphite flakes. This suggests the reason for the parabolic type stress-strain diagrams. The effect of phosphorus in promoting rigidity is well known. (J. W. Bolton, Trans. A. F. A., Vol. 32, p. 527; Jas. T. MacKenzie, Trans. A. F. A., Vol. 33; J. W. Bolton, Trans. A. F. A., Vol. 33, p. 467 (discussion); Jas. T. MacKenzie, Trans. A. F. A., Vol. 34.)

the groups to include even the so-called inherent qualities, by extending the above methods to cover other properties, it should be possible to evolve a quantitative system for predicting the properties of gray iron. This is no idle fancy. Indeed, every forward step predicts it. More statistical research, more experimental investigations, more systematic correlation, then more intelligible order will be apparent in the seemingly chaotic metallurgy of gray iron.

Carbon + 0.30 × Silicon

Carbon and silicon are the potent variables in composition. Taking the same sized bars (hence cooling rates nearly constant), several investigators have plotted the above variables against the mechanical tests. For example, MacKenzie plotted deflection at 1,500 lbs. (pipe bar) against $C + \frac{Si}{4}$ (Proceedings ASTM—1925). The writer plotted transverse strengths of the old ASTM bar against the cumulative percentages of silicon and carbon (Trans. A. F. A., 1924. See Fig. 11.) This worked out fairly well for the 1.25" bar. However, it did not apply to larger bars. Applying the principle utilized in attempting a systematic classification of graphite flakes formations* an attempt is made here to define the position of the bar along the horizontal line (i. e., the per cent carbon line) of the iron carbon diagram.[12]

This is a crude way of indicating by *chemical analysis the graphitic structure of the metal and establishing relation of the same to certain mechanical properties.* This is tested out in Figs. 17 to 21 inclusive. The method certainly appears more worthy of attention than the silicon plus carbon ratio, particularly in bars removed from the so-called arbitration diameters.[13]

Two other things are apparent from even casual inspection of the data and charts.

*Bolton, J. W., *Some Graphite Formation in Gray Cast Iron*, Trans. A. F. A., Vol. 35, p. 386 (1927).

[12] This is done on the assumption that each 1.0 per cent silicon lowers the eutectic percentage of carbon some 0.30 per cent (as shown by Wüst) within the ranges we are interested in. Thus we say that with 4.2 per cent carbon we have the eutectic in silicon free irons. However, the same point is obtained with carbon 3.50 and silicon 2.33, or carbon 3.30 and silicon 3.00. Or an iron 3.30 carbon and silicon 2.50 is similar in this respect to an iron 3.40 carbon and 1.95 silicon.

[13] It seems that these "arbitration" bars are most successful in minimizing the effects of composition on strength. This was noted many years ago by Keep.

These are:—*(1) Steel has a direct effect. (2) While nickel may not always strengthen small sections, it materially increases the strength of larger sections.*

Summary

The term gray cast iron covers a series of iron-carbon-silicon alloys. It is suggested that these alloys be divided into groups, according to their percentages of silicon and of carbon. This is the first step toward their systematic study.

It is necessary to study the effect of cooling rate upon metals as cast from each group. Use of the $\frac{volume}{surface\ area}$ ratio gives an approximation of the relative cooling rate.

To make test data on bars of practical value such data must be correlated to tests from actual castings. This may be done with a fair degree of accuracy by choosing test bars of approximately the same relative cooling rates as the castings.

Limitations of some testing methods are enumerated. The tensile test deserves wider use. Recent methods of conducting shear and uniformity tests are explained.

A large amount of data on various sized bars of different composition groups is assembled in the summary, Table 5. More thorough and extensive correlation of test data will make possible a quantitative system for predicting many of the properties of gray iron.

Use of the sum *per cent carbon* + *0.30 per cent silicon* is advocated for indicating the cumulative effect of these elements on some of the mechanical properties of bars.

Conclusions

A general conclusion which may be drawn from this paper is that extension of *systematic* research will furnish foundrymen proper information on the properties of their product. With this knowledge, and through its dissemination to the engineering public, intelligent extension of engineering applications for gray iron castings can be expected.

The job of obtaining such information is a large one, and

undoubtedly all thinking foundrymen are prepared to back it up, both financially and morally.

It is self evident, from the data of this paper, that at the present stage of our knowledge, the so-called arbitration bars are very poor "measuring rods" for the quality of gray iron in castings. In 1924 the writer said* "until more research data is available it is best to stick to the present standard bar. . . . Research and practical experience determine the relation of the bars to the castings. In the four years since preparation of that paper, many more research data have been made available, both in this country and abroad. Therefore, it now seems expedient that the testing societies give serious consideration to use of more than one bar, and serious and concerted effort be made to indicate the correlation of the bars to castings. However, this suggestion is not the main object of this paper, and it is hoped that mention of this controversial point will not obscure the real points at issue.

The writer is deeply indebted to the splendid work of many investigators, both in this country and abroad. Study of their work has proved very valuable, and has aided in preparation of this paper. Especial thanks are given The Lunkenheimer Company, through whose courtesy it is possible to present this paper to this Association.

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*Bolton, J. W., *Notes on Composition and Structure of A. S. T. M. Bar*, Trans. A. F. A., Vol. 32, pt. 1, p. 534.

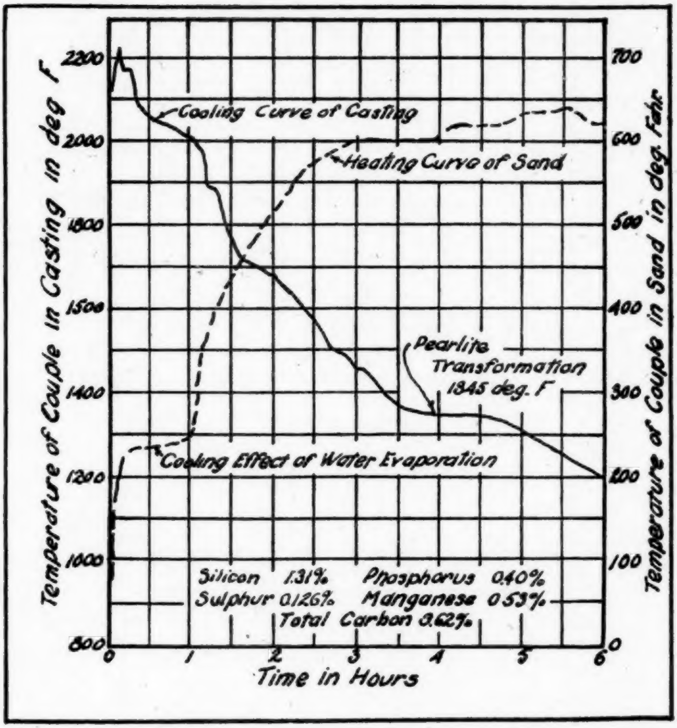


FIG. 1—COOLING RATE OF A CASTING AND HEATING CURVE OF SAND IN MOLD

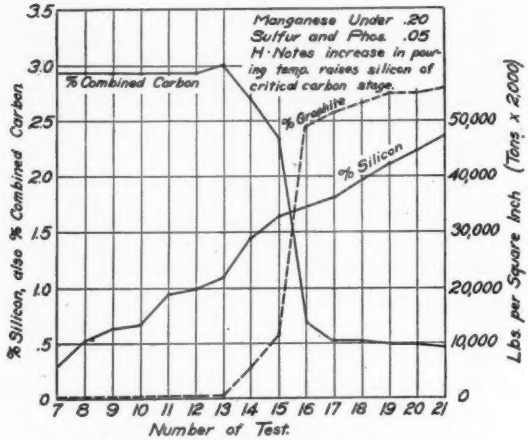


FIG. 2—SILICON GRADIENT

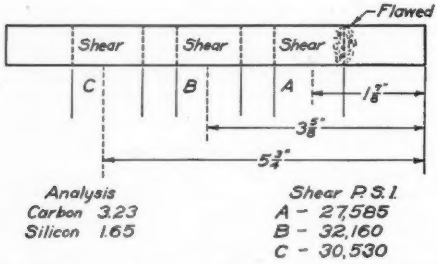


FIG. 3—CASTING OF CASE 1—SHEAR ON 1½ INCH CASTING

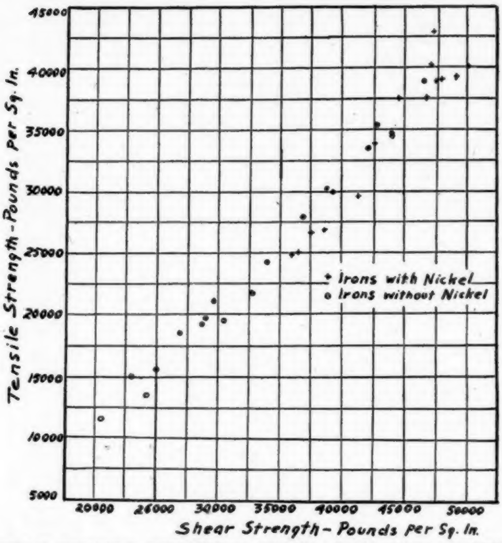


FIG. 4—SHEAR-TENSILE STRENGTH CHART—RELATION OF TENSILE TO SHEAR ON 0.505 INCH BAR. FOR THE DATA OF THIS FIGURE SEE TABLE 7 ON PAGE 497

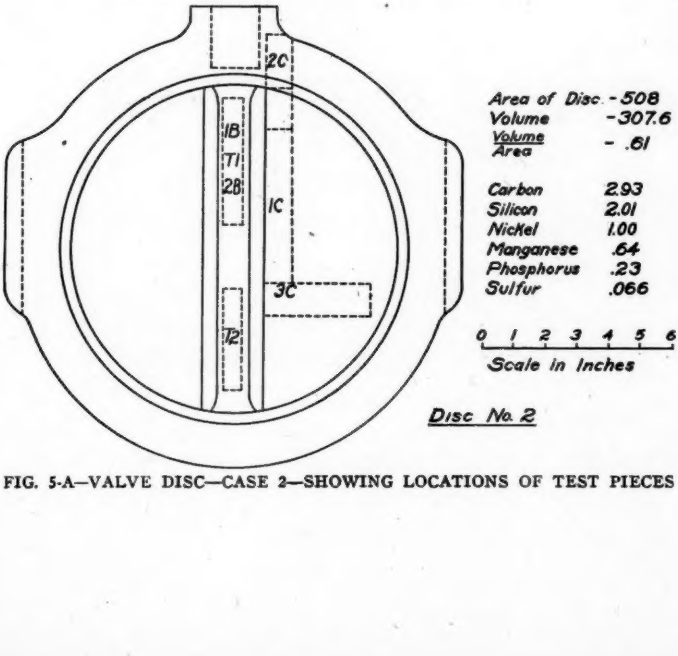


FIG. 5-A—VALVE DISC—CASE 2—SHOWING LOCATIONS OF TEST PIECES

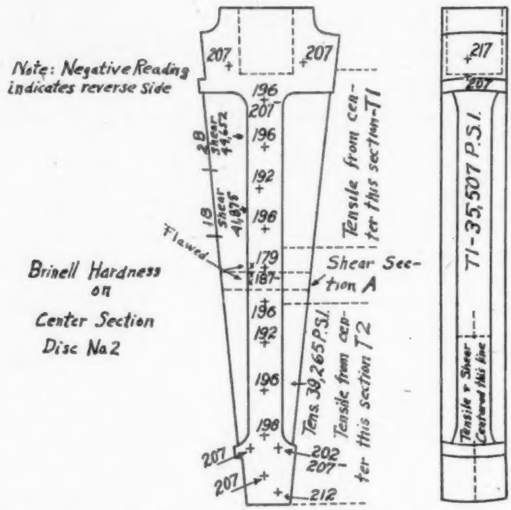


FIG. 5-B—VALVE DISC—CASE 2—GIVING TENSILE, SHEAR AND BRINELL TEST READINGS

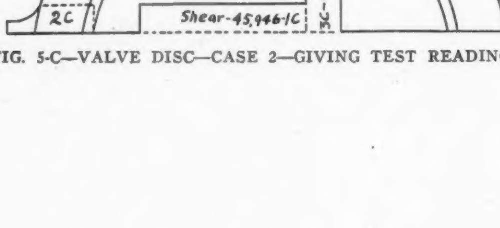


FIG. 5-C—VALVE DISC—CASE 2—GIVING TEST READINGS

Table 7

DATA TO GO WITH FIG. 6. RELATION OF SHEAR AND TENSILE

SHEARS ON 0.505 INCH BAR, DOUBLE SHEAR, CALCULATED TO PER SQUARE INCH. ALL BARS CAST 21–22 INCHES

Serial	Shear Strength* Lbs. per Sq. In.	Diameter Cast in Inches	Tensile Strength Lbs. per Sq. In.	Diameter Pulled in Inches	Per Cent Silicon	Per Cent Carbon	Per Cent Phosphorus	Per Cent Manganese	Per Cent Sulphur	Number Tested
Nickel Free Irons										
1	46,554	0.75	38,860	0.505	1.68	3.24	0.33	0.46	0.083	4
2	44,020	1.00	34,575	0.686	1.68	3.31	0.33	0.46	0.083	4
3	43,870	0.75	34,718	0.505	1.71	3.51	0.36	0.48	0.087	4
4	42,755	1.00	35,380	0.686	2.46	3.31	0.30	0.57	0.055	2
5	42,165	1.20	33,449	0.686	...	...	...	...	....	2
6	39,285	1.00	29,885	0.686	1.71	3.51	0.36	0.48	0.087	4
7	38,800	0.75	30,243	0.500	2.17	3.53	0.32	0.60	0.086	4
8	36,800	1.20	27,899	0.686	...	...	...	...	....	2
9	33,960	2.00	24,248	0.800	1.68	3.17	0.33	0.46	0.083	3
11	32,850	1.00	21,744	0.360(?)	2.17	3.54	0.32	0.60	0.086	3
12	31,525	3.00	19,519	0.800	1.68	3.04	0.33	0.46	0.083	3
13	29,700	2.00	21,060	0.800	2.35	3.16	0.27	0.58	0.042	2
14	29,075	1.20	19,694	0.686	...	...	...	...	....	2
15	28,800	1.20	19,234	0.686	...	...	...	...	....	2
16	26,895	2.00	18,475	0.800	1.71	3.48	0.36	0.48	0.087	3
17	24,900	3.00	15,657	0.800	2.95	2.38	0.27	0.58	0.048	3
18	24,325	2.00	13,485	0.800	2.17	3.47	0.32	0.60	0.086	3
19	23,465	3.00	15,056	0.800	1.71	3.15	0.36	0.48	0.087	3
20	20,500	3.00	11,561	0.800	2.17	3.43	0.32	0.60	0.086	3
Nickel Irons										
1	50,050	1.00	40,162	0.686	...	...	...	...	....	3
2	49,125	1.00	39,136	0.686	...	...	...	...	....	3
3	47,800	1.20	39,068	0.686	...	...	...	...	....	2
4	47,210	1.00	42,910	0.686	1.75	2.69	0.28	0.62	0.060	4
5	47,125	1.20	40,187	0.686	...	...	...	...	....	2
6	46,738	3.00	36,570	0.800	1.75	2.65	0.28	0.62	0.060	3
7	45,765	2.00	38,800	0.800	1.75	2.54	0.28	0.62	0.060	3
8	44,412	0.75	37,415	0.750	1.76	3.29	0.16	0.61	0.079†	10
9	42,500	2.00	33,860	0.800	...	...	...	...	....	1
10	41,200	2.00	29,617	0.800	...	...	...	...	....	2
11	38,425	2.00	26,880	0.800	1.76	3.29	0.16	0.61	0.079†	6
12	37,425	3.00	26,664	0.800	...	...	...	...	....	3
13	36,450	3.00	24,937	0.800	...	...	...	...	....	3
14	35,962	3.00	24,815	0.800	1.76	3.29	0.16	0.61	0.079†	6

*Speed of applying shear 0.016 inch per minute. †Nickel 1.26 per cent, pulled with skin on.

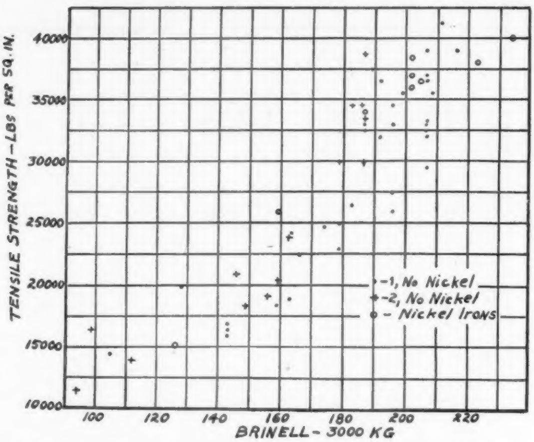


FIG. 6—RELATION OF BRINELL NUMBER TO TENSILE STRENGTH. WHILE THERE IS A GENERAL RELATIONSHIP THIS IS NOT CLOSE ENOUGH FOR REDUCTION TO AN ACCURATE FORMULA

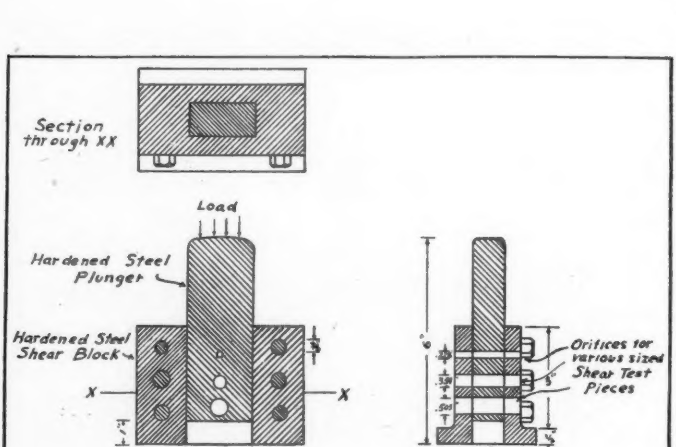


FIG. 7—DEVICE FOR MAKING SHEAR TESTS—THIS DEVICE MAY BE USED ON ANY UNIVERSAL TESTING MACHINE

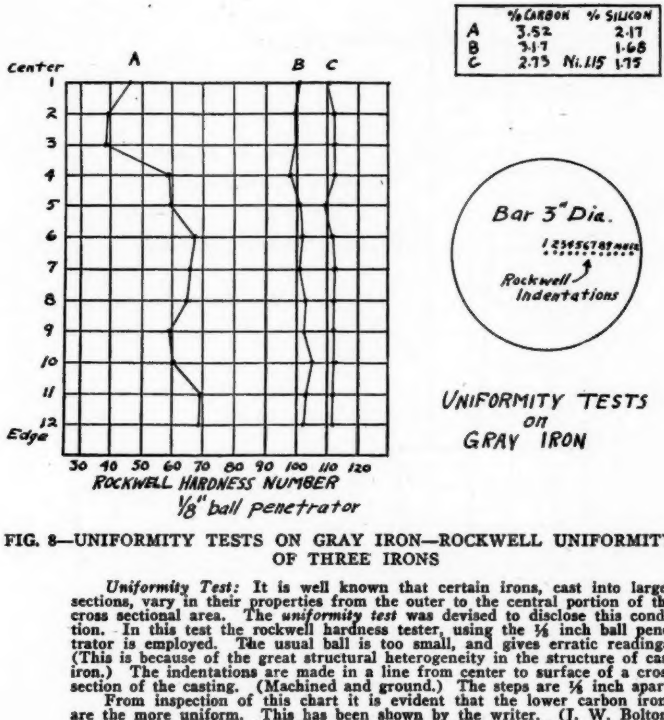


FIG. 8—UNIFORMITY TESTS ON GRAY IRON—ROCKWELL UNIFORMITY OF THREE IRONS

Uniformity Test: It is well known that certain irons, cast into larger sections, vary in their properties from the outer to the central portion of the cross sectional area. The *uniformity test* was devised to disclose this condition. In this test the rockwell hardness tester, using the 1/8 inch ball penetrator is employed. The usual ball is too small, and gives erratic readings. (This is because of the great structural heterogeneity in the structure of cast iron.) The indentations are made in a line from center to surface of a cross section of the casting. (Machined and ground.) The steps are 1/8 inch apart.

From inspection of this chart it is evident that the lower carbon irons are the more uniform. This has been shown by the writer. (J. W. Bolton, Exchange Paper, Belgian Foundrymen's Association, 1925.) It is also apparent from physical test data included in tables presented in this paper.

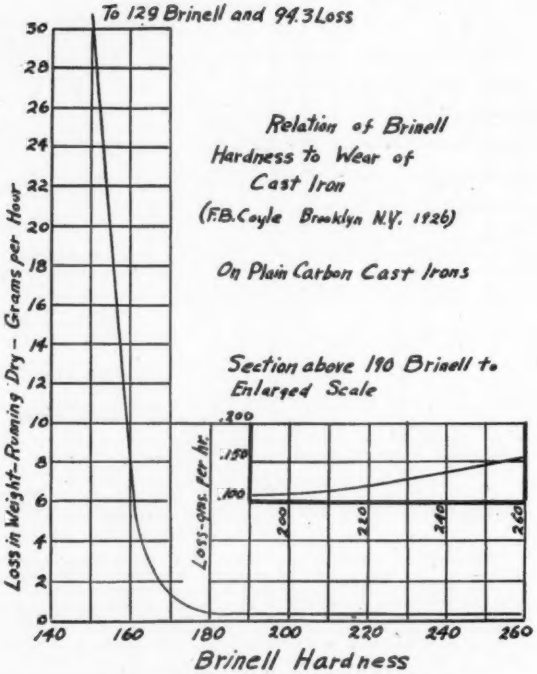


FIG. 9—RELATION OF BRINELL TO WEAR (F. B. COYLE)

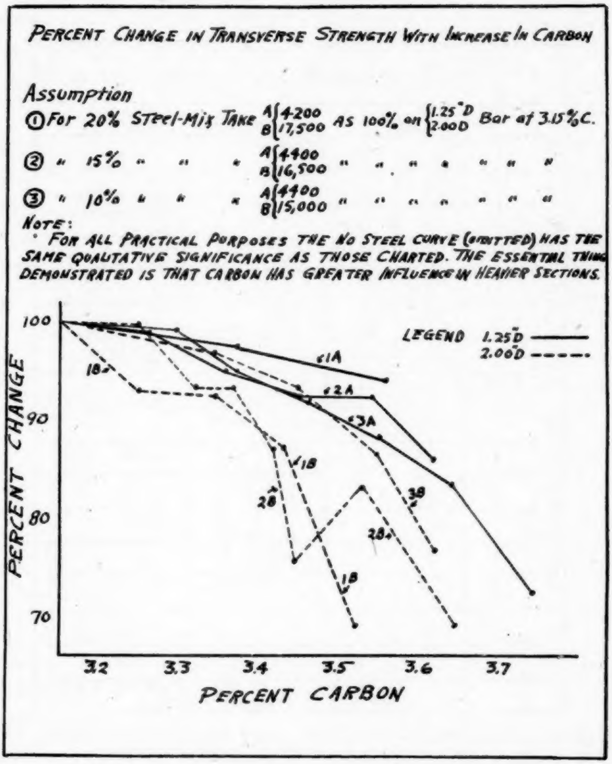


FIG. 10—CHANGE IN TRANSVERSE STRENGTH WITH INCREASE IN CARBON (FROM J. W. BOLTON, A. F. A. EXCHANGE PAPER TO BELGIUM ASSOCIATION, 1925)

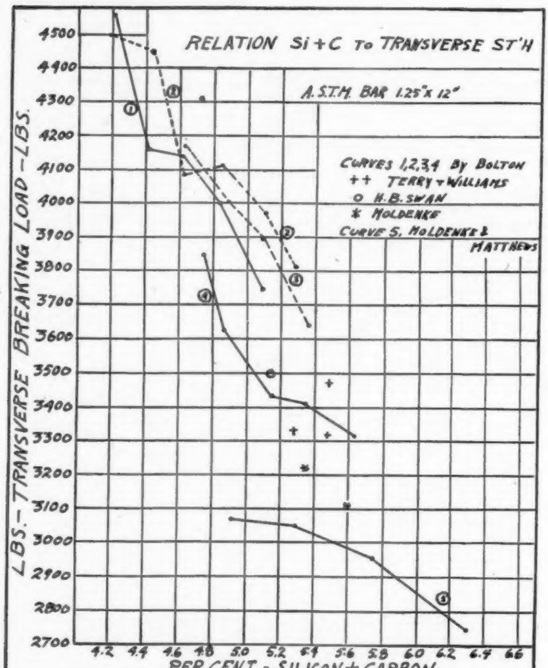


FIG. 11—RELATION OF THE PER CENT SILICON PLUS PER CENT CARBON TO TRANSVERSE STRENGTH

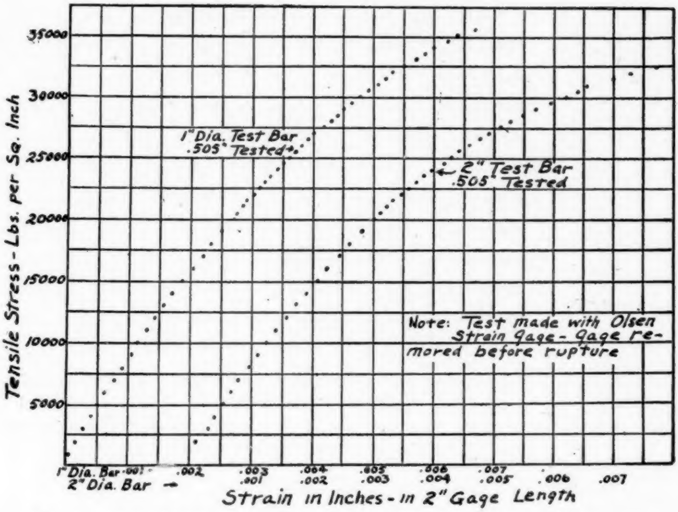


FIG. 12—STRESS-STRAIN CURVE ON LOW CARBON—SEMI-STEEL MIX

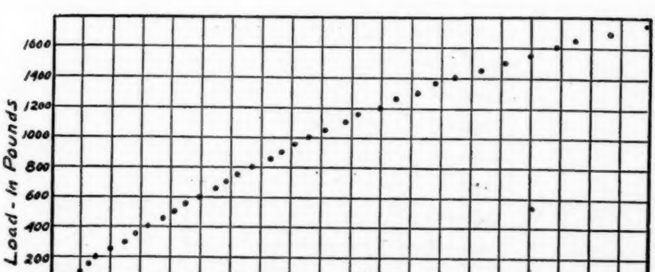


FIG. 13-A—TRANSVERSE DEFLECTION—ON 1 INCH DIAMETER BAR OF LOW CARBON, HIGH SILICON IRON

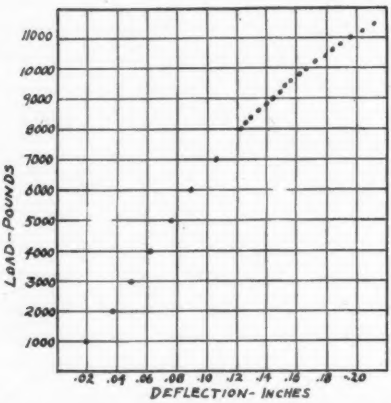


FIG. 13-B—TRANSVERSE DEFLECTION—ON 2 INCH DIAMETER BAR OF LOW CARBON, HIGH SILICON IRON

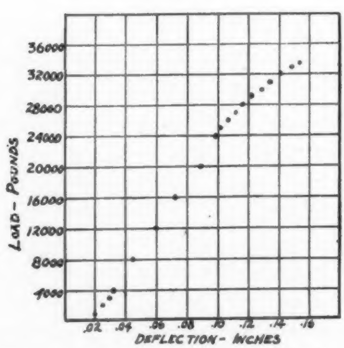


FIG. 13-C—TRANSVERSE DEFLECTION—ON 3 INCH DIAMETER BAR OF LOW CARBON, HIGH SILICON IRON

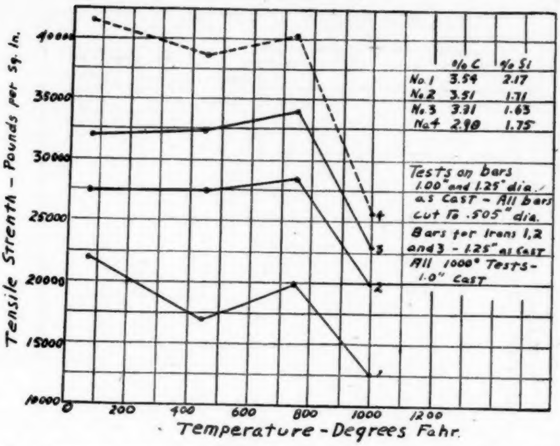


FIG. 14—TENSILE STRENGTH TESTS ON VARIOUS IRONS AT ELEVATED TEMPERATURES

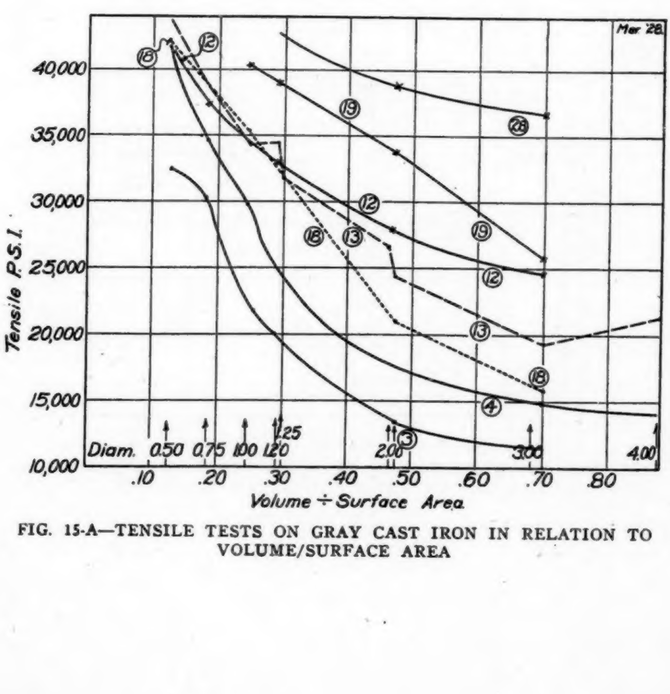


FIG. 15-A—TENSILE TESTS ON GRAY CAST IRON IN RELATION TO VOLUME/SURFACE AREA

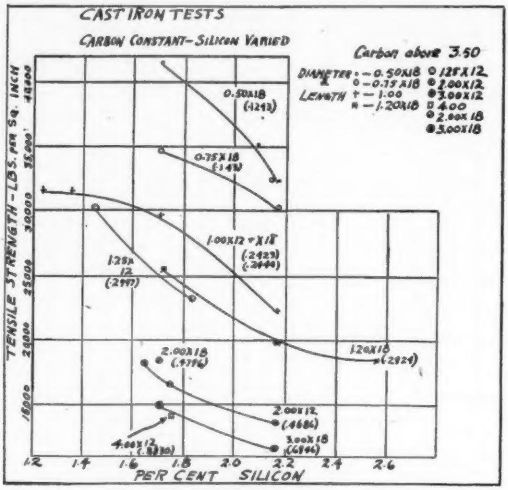


FIG. 15-B—TENSILE TESTS ON GRAY CAST IRON IN RELATION TO SILICON CONTENT WITH CARBON CONSTANT

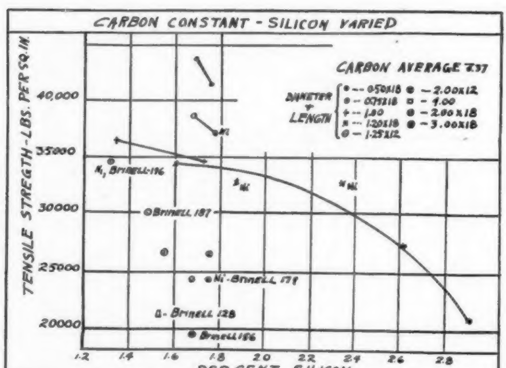


FIG 15-C—TENSILE TESTS ON GRAY CAST IRON IN RELATION TO SILICON CONTENT WITH CARBON CONSTANT

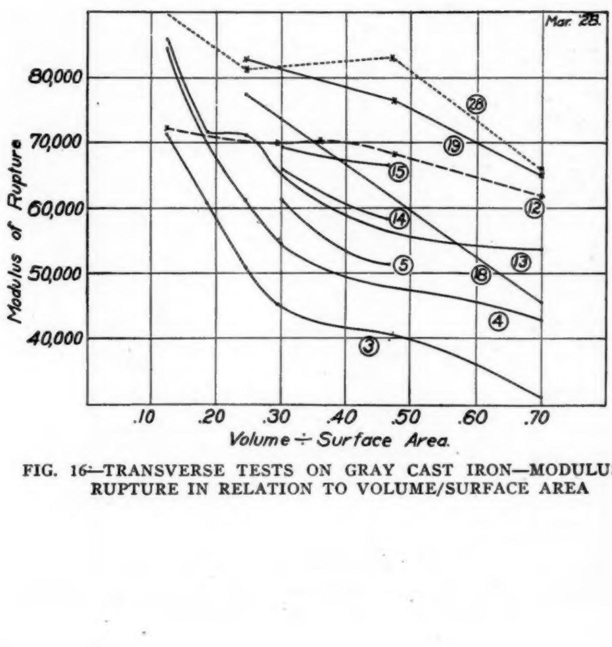


FIG. 16—TRANSVERSE TESTS ON GRAY CAST IRON—MODULUS OF RUPTURE IN RELATION TO VOLUME/SURFACE AREA

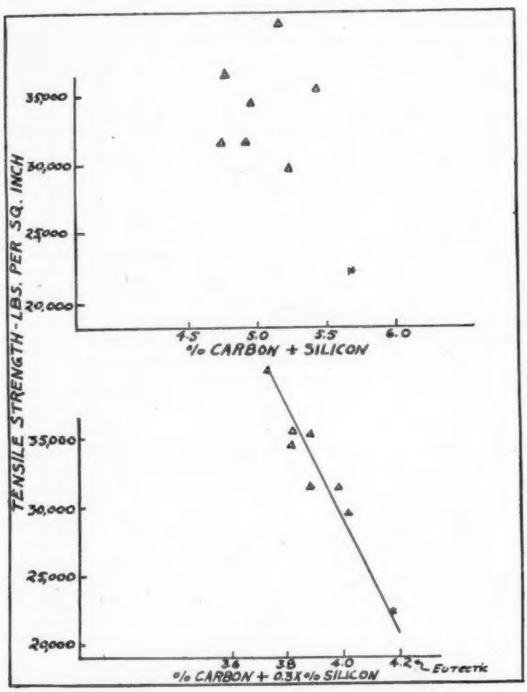


FIG. 17—TENSILE STRENGTH IN RELATION TO SILICON PLUS CARBON PER CENT ON 1 INCH DIAMETER BAR

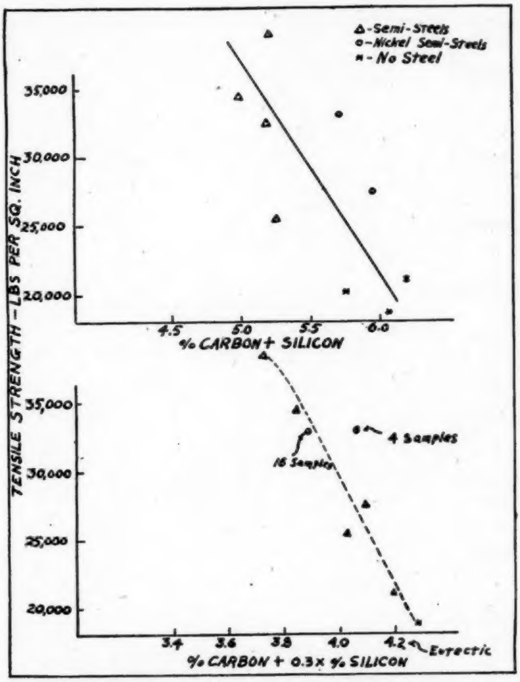


FIG. 18—TENSILE STRENGTH IN RELATION TO SILICON PLUS CARBON PER CENT ON 1.20 INCH DIAMETER BAR

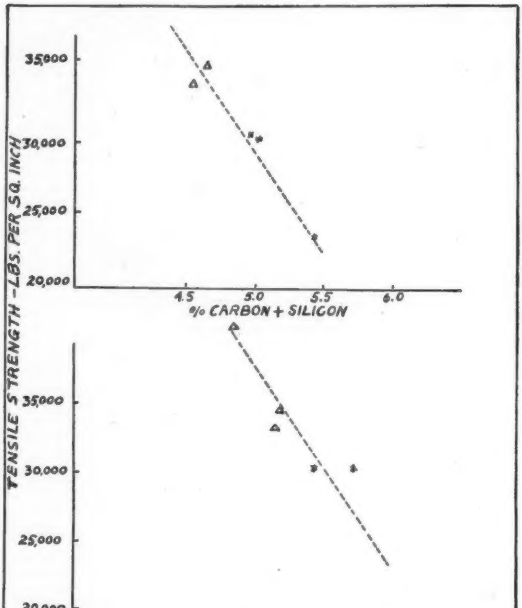


FIG. 19—TENSILE STRENGTH IN RELATION TO SILICON PLUS CARBON PER CENT ON 1.25" DIAMETER BAR

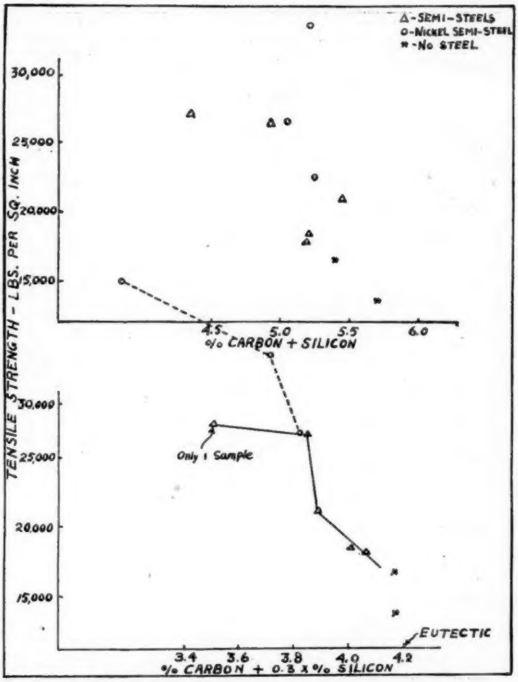


FIG. 20—TENSILE STRENGTH IN RELATION TO SILICON PLUS CARBON PER CENT ON 2 INCH DIAMETER BAR

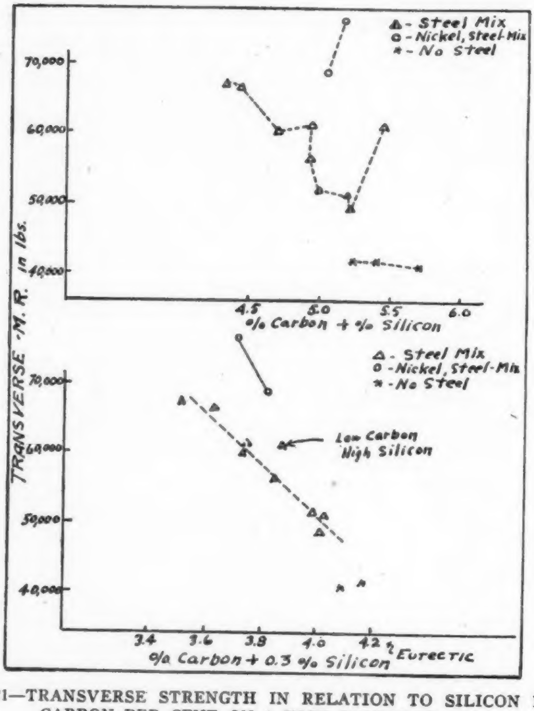


FIG. 21—TRANSVERSE STRENGTH IN RELATION TO SILICON PLUS CARBON PER CENT ON 2 INCH DIAMETER BAR

Reducing Scrap in the Malleable Foundry

By R. A. Greene,* Mansfield, O.

People, and especially the American people, seem to have an inborn, insatiable desire for gaming. Innumerable examples of this are everywhere present. Baseball, bowling, horse racing, golf and yacht racing are some of the more prominent. For example, think of the old Mississippi river steamboat races, where not only the boats themselves were in danger but also the very lives of the passengers. Did this danger to human life dampen the ardor or enthusiasm of the game? No! Many of the passengers were ready to feed their own belongings into the boilers in order to furnish steam to beat the opposing boat! Also, read the story of Andrew Carnegie and the Lucy furnace. What was the impelling motive among the workers? Was it not the great game, "Beat the Record?"

If two men are set to do similar jobs it seems to be human nature for each to try to equal or excel the other; the money part is apparently a secondary consideration. Of course, if the workers sense an idea that industry is trying to capitalize their gaming instincts to avoid paying them fairly for their efforts, the plan will lose much of its effectiveness.

Many schemes are devised for reducing the scrap in the foundry. Many think that the money, that is penalization, is the most

*Assistant Manufacturing Superintendent, Ohio Brass Co.

effective incentive to get the molder to make a high percentage of good castings. However, after much experience in work of this kind I am not so sure of this.

After much reflection upon past experience, the method or plan, the description of which is the object of this paper, was finally decided upon. The plan, which is based on the gaming instinct of human nature, has now been in operation for about four years, a sufficient length of time to prove its worth.

For purpose of description I have divided this subject into four divisions: the daily sheet, the weekly sheet, the quarterly chart, and the fruitage or the results that have been achieved since this plan has been in operation.

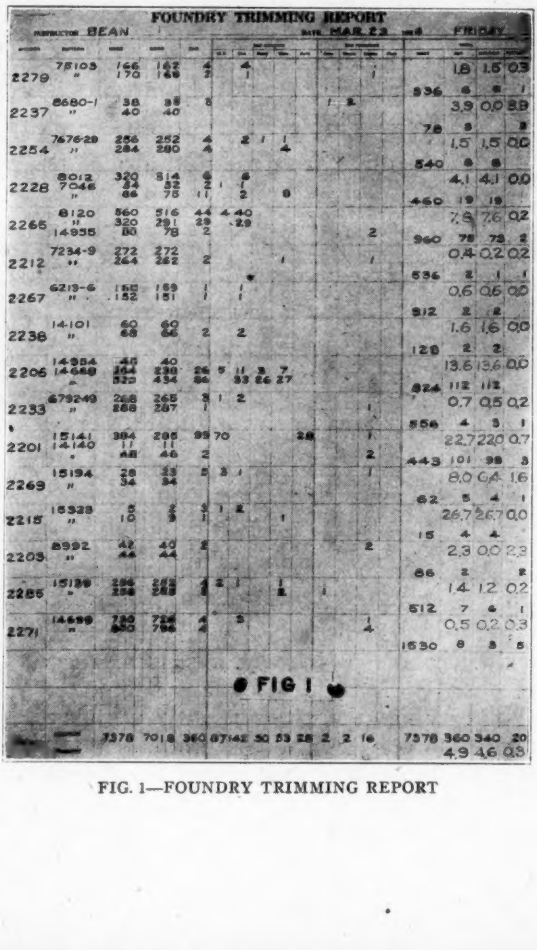
The Daily Sheet

The molding department of our malleable foundry is divided into four groups of not more than eighteen molders each. Each group is in charge of an instructor, whose duties are practically the same as a sub-foreman and who looks to the general foreman for his directions.

To have a record of each group as a whole, and at the same time to use this record to display each molder's daily activities, that is, the patterns he works, the good and bad castings he makes, and the reason why the defective castings are bad, the daily sheet, which we call the foundry trimming report, and which is shown in Fig. 1, was designed. On this sheet spaces are provided for recording the activities of eighteen molders. It is printed on heavy yellow paper, 14 inches by 21 inches, has eighteen vertical columns and eighteen main horizontal spaces. Each main horizontal space is again sub-divided into four spaces from column two to column fourteen, inclusive, and into two spaces for the last four columns. The four smaller horizontal spaces are for exhibiting four different patterns. While a molder is not supposed to work more than one pattern in a day he will often run a job out and have to start another. To take care of this and other emergencies and also to keep the daily sheet from becoming crowded the four spaces were provided. When a molder works but one pattern one space is used for the morning heat and one for the afternoon heat. In the last four columns, headed "Totals," the lower half of each main horizontal space is used to record

each molder's daily totals as designated at the heads of the colunms; the upper half being used for the percentage figures. In the first left hand column is recorded the molder's clock number. In the next four columns, the patterns the molder works, the total castings the molder makes, the good, and the bad. In the next five columns, headed bad molding, is recorded the number of castings rejected on account of misrun, dirt, swell, blow, and shift. In the next four columns headed bad founding, is recorded the number of castings rejected for defects chargeable to bad cores, shrinks, broken castings, and floor loss.

Floor loss is not bad founding, neither is it bad molding. It



FOUNDRY TRIMMING REPORT

BEAN — MAR 23 — FRIDAY

2279	75105 / "	166 / 170	162 / 168	4 / 2	4 / 1 ; 1	336	6	5	1
							1.8	1.5	0.3
2237	8680-1 / "	38 / 40	35 / 40	3	1 2	78	3		3
							3.9	0.0	3.9
2254	7676-20 / "	256 / 284	252 / 280	4 / 4	2 1 1 / 4	540	8	8	
							1.5	1.5	0.0
2228	8012 / 7046 / "	320 / 34 / 86	314 / 32 / 75	6 / 2 / 11	6 / 1 1 / 2 9	460	19	19	
							4.1	4.1	0.0
2265	8120 / " / 14955	560 / 320 / 80	516 / 291 / 78	44 / 29 / 2	4 40 / 29 ; 2	960	75	73	2
							7.8	7.6	0.2
2212	7234-9 / "	272 / 264	272 / 262	2	1 ; 1	536	2	1	1
							0.4	0.2	0.2
2267	6219-6 / "	160 / 152	159 / 151	1 / 1	1 / 1	312	2	2	
							0.6	0.6	0.0
2238	14101 / "	60 / 68	60 / 66	2	2	128	2	2	
							1.6	1.6	0.0
2206	14984 / 14689 / "	40 / 264 / 520	40 / 238 / 434	26 / 86	5 11 3 7 / 33 26 27	824	112	112	
							13.6	13.6	0.0
2233	679249 / "	268 / 288	265 / 287	3 / 1	1 2 ; 1	556	4	3	1
							0.7	0.5	0.2
2201	15141 / 14140 / "	384 / 11 / 48	285 / 11 / 46	99 / 2	70 28 ; 1 / 2	443	101	98	3
							22.7	22.0	0.7
2269	15194 / "	28 / 34	23 / 34	5	3 1 ; 1	62	5	4	1
							8.0	6.4	1.6
2215	15328 / "	5 / 10	2 / 9	3 / 1	1 2 / 1	15	4	4	
							26.7	26.7	0.0
2203	8992 / "	42 / 44	40 / 44	2	2	86	2		2
							2.3	0.0	2.3
2285	15139 / "	286 / 256	282 / 253	4 / 3	2 1 1 / 2 1	512	7	6	1
							1.4	1.2	0.2
2271	14699 / "	730 / 800	726 / 796	4 / 4	3 ; 1 / 4	1530	8	3	5
							0.5	0.2	0.3
		7378	7018	360	87 142 50 53 28 2 2 16	7378	360	340	20
							4.9	4.6	0.3

FIG 1

FIG. 1—FOUNDRY TRIMMING REPORT

is the difference between the bad plus the good, and the total made. It is usually a shortage; it may be, but seldom is, an average. If it is a shortage it is deducted from the molder the same as bad molding. A shortage was formerly one of the big losers. One day we accidentally discovered a molder secretly disposing of several castings, which, had they gone through to the inspector, would have been classed under bad molding. This experience made us realize that sometimes it is necessary to do some things which on the face do not look to be quite fair.

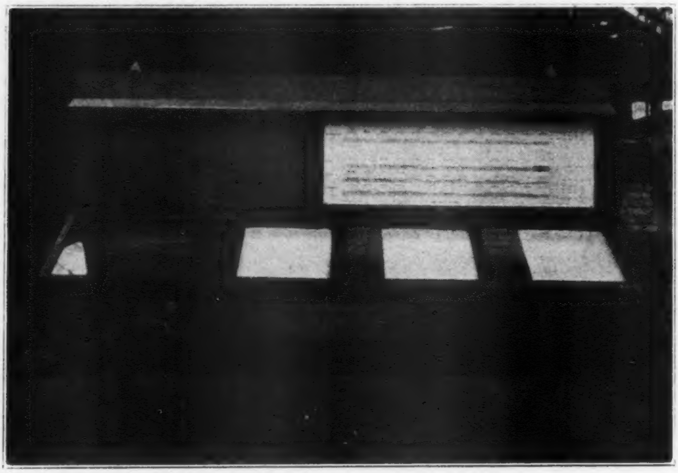


FIG. 2—BULLETIN BOARD

Nevertheless, after charging floor loss to the molder the floor loss practically disappeared.

When the molders' activities are all posted on this daily sheet, the sheet added up and the percentages figured, they are displayed on the bulletin board. To attract attention the bulletin board, shown in Fig. 2, was purposely made rather elaborate. It is divided into four sections, a section for each instructor.

We begin by displaying Monday's sheet for each group. When Tuesday's sheet is displayed it is put over and covers Monday's sheet with the exception of the last three columns. In the same manner Wednesday's sheet is put over Tuesday's, Thurs-

day's over Wednesday's, and so on, always arranging them so as to exhibit the last three columns of the day previous. As the molders have been kept in the same rotation on the daily sheets, each molder's record can easily be seen for the entire week. This arrangement is shown in Fig. 3. Monday's and Saturday's sheets are not here because the foundry did not work on those days.

The Weekly Sheet

The weekly sheet shown in Fig. 4 is used to collect the daily totals of each instructor's group. It is a sheet 11 inches by 12 inches and has the same headings under "Bad Castings" as the daily sheet. The instructor's name appears in the left hand column, the number of molders in the second column and the day of the week, Monday, Tuesday, Wednesday, Thursday, Friday

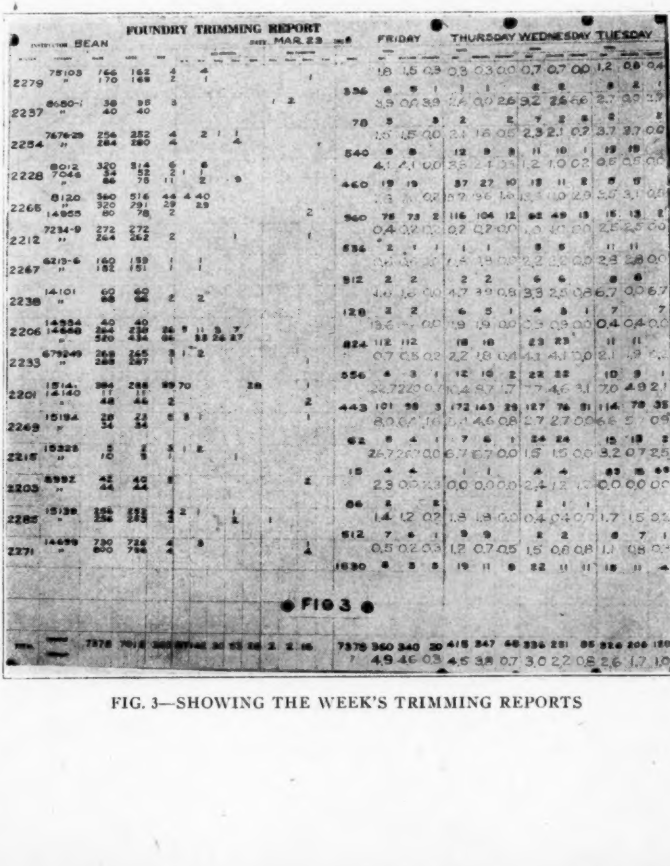


FIG. 3—SHOWING THE WEEK'S TRIMMING REPORTS

and Saturday, in the third column. In the last six columns is displayed the total bad, which is made up of bad molding and bad founding, and the per cent that each of these is to the total made.

At the end of the week the totals for each group, the grand total, and the weekly percentages are determined. The quarterly sheet is marked up and one copy of the weekly sheet is forwarded to the general foreman of the foundry, one being filed for future reference. These sheets are very valuable, being referred to frequently for various investigations, information, etc. The weekly percentage of each instructor as shown on this sheet is the basis of that instructor's bonus.

The Quarterly Sheet

The quarterly sheet is the picture of the foundry's progress from day to day, and from week to week for each quarter or each

MALLEABLE FOUNDRY

WEEKLY REPORT DAILY LOSS SUMMARY WEEK No. 12 ENDING MAR. 24, 1928

INSTRUCTOR	MEN	DAY	MADE	BAD MOULDING M.R.	DIRT	[illegible]	[illegible]	[illegible]	BAD FOUNDING [illegible]	[illegible]	[illegible]	[illegible]	TOTAL BAD NO.	%	MOULDING	%	FOUNDRY NO.	%
		M																
	16	T	12647	47	72	80	7		8	1	111		326		206		120	
BEAN	16	W	11259	23	159	66	3		5	2	78		336		251		85	
	16	T	9177	58	178	6	11	94	2		66		415		347		68	
	16	F	7378	87	142	30	53	28	2	2	16		360		340		20	
		S																
	TOTAL		40281	215	551	182	74	122	17	5	271		1437		1144		293	
	PER C'T.																	
		M																
	15	T	8793	32	99	9	3		2		7		152		143		9	
GETTLES	15	W	9610	6	132	5	3		9		9		164		146		18	
	15	T	9528	2	97	8	4				13		124		111		13	
	15	F	9975	20	47	29	1		3	2	11		113		97		16	
		S																
	TOTAL		37906	60	375	51	11		14	2	40		553		497		56	
	PER C'T.																	
		M																
	14	T	10628	76	261	171	1		1		29		539	5.1	509		30	
KINDINGER	14	W	11550	67	186	46	6		67		15		387		305		82	
	14	T	12068	89	91	42	16	1	12	1	17		269		239		30	
	14	F	12202	134	123	22	48	17	2		22		368		344		24	
		S																
	TOTAL		46448	366	661	281	71	18	82	1	83		1563		1397		166	
	PER C'T.																	
		M																
		T																
		W																
		T																
		F																
		S																
	TOTAL																	
	PER C'T.																	
GRAND TOTAL	NUMBER		124635	641	1587	514	186	140	113	8	394		3553		3038		515	
	PER C'T.																	

FIG 4

FIG. 4—WEEKLY REPORT

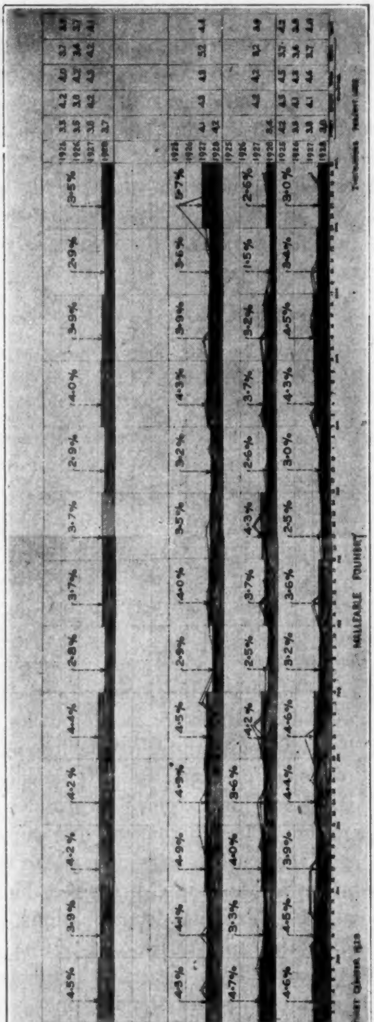


FIG. 5—SHOWING LOSSES UNDER EACH INSTRUCTOR BY WEEK AND COMPARED WITH OTHER YEAR AVERAGES

thirteen weeks of the year. This sheet, Fig. 5, is 20 inches by 60 inches and is displayed on the upright part of the bulletin board. Ruled on it are spaces for thirteen weeks, four instructors, and the weekly totals. When the daily sheets are displayed each instructor's daily per cent of total bad and per cent of bad molding are plotted in as shown by the broken line. At the end of the week the total loss of each group and the total weekly loss is blocked in in red or blue, red for a loss of five per cent or greater, blue for a loss of less than five per cent. Every one, as you can readily imagine, dislikes a *red* display.

Gathering and Making the Figures

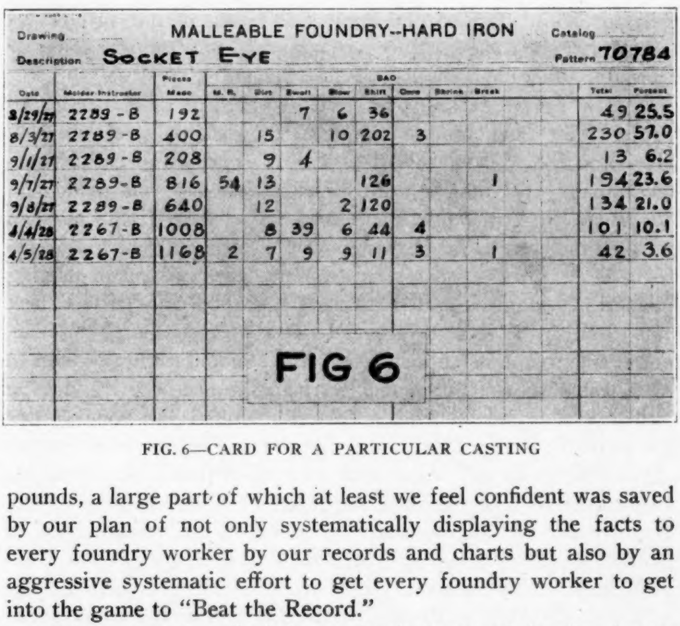
Our foundry, always having been a piece work shop, paid the molder for the molds he made less the defective castings appearing under bad molding. Consequently it had methods for collecting this information which are probably similar to other shops. To get the figures for the present scheme it only required a slight rearrangement of the existing methods of gathering the information that was already required to pay the molder. This was easily accomplished without increasing the existing clerical work. In fact, in designing the entire scheme, the avoidance of extra clerical work or unnecessary record making was another thing that was always in mind.

Under the present system when each molder's castings have been shaken out, piled alongside his floor and cooled off, the gates and sprues are knocked off, the castings are put into suitable containers, taken to the sand blast and, after being sand blasted, are delivered to the "trimmer" or inspector. He finishes the cleaning, that is, chips off any small lumps, gates or protuberances that the sand blasting operation failed to remove, and sorts the castings into good and bad. The bad castings then go to the chief trimmer, who divides them into mis-run, dirt, swell, blow, shift, core, shrink, or broken. He lists his determinations in the proper column on the daily sheet and, at the end of the day when the sheet is finished, forwards it to the manufacturing superintendent's division. Here the division's stenographer, with the aid of the slide rule, with a special set-up which any girl seems to learn readily, determines and records on the sheets the different percentages. Red figures for a per cent of five or greater, and blue

for less than five. She then turns the sheets over to the supervisor of this work who takes them to the foundry, displays them on the bulletin board and marks up the quarterly sheet.

Results

That this scheme actually gave results is proved to us by the reduction in scrapped castings in our malleable foundry. For the years 1924, 1925, 1926 and 1927 the loss averaged 5.3 per cent against 9.8 per cent for the previous years. The difference between 9.8 per cent and 5.3 per cent represents, in round numbers, 465,000 pounds a year, or, for the four years, 1,860,000



MALLEABLE FOUNDRY--HARD IRON

Drawing ...... Catalog ......

Description SOCKET EYE Pattern 70784

Date	Molder Instructor	Pieces Made	Bad: M. R.	Dirt	Swell	Blow	Shift	Core	Shrink	Break		Total	Percent
8/29/27	2289-B	192			7	6	36					49	25.5
8/3/27	2289-B	400		15		10	202	3				230	57.0
9/1/27	2289-B	208		9	4							13	6.2
9/7/27	2289-B	816	54	13			126			1		194	23.6
9/8/27	2289-B	640		12		2	120					134	21.0
4/4/28	2267-B	1008		8	39	6	44	4				101	10.1
4/5/28	2267-B	1168	2	7	9	9	11	3		1		42	3.6

FIG 6

FIG. 6—CARD FOR A PARTICULAR CASTING

pounds, a large part of which at least we feel confident was saved by our plan of not only systematically displaying the facts to every foundry worker by our records and charts but also by an aggressive systematic effort to get every foundry worker to get into the game to "Beat the Record."

I have now described the mechanical part of the plan in use at the Ohio Brass Company for reducing scrap in the malleable foundry. Always in mind, in designing this plan, was the idea of appealing to the gaming instincts of the foundry workers which, as I said in the beginning, is an inborn characteristic of all Amer-

ican working men. If something could be done to incite the molders, and not only the molders but the rest of the foundry workers as well, to do some real constructive thinking about their problems, seeking information from the technical department as well as from other available sources, and to cooperate with each other with the earnestness, "head-work" and team work as enthusiastically as these characteristics exist in a real ball team, much good could be accomplished toward economical production of "quality castings" with a low scrap loss. I also have given in several instances reasons for various steps in this plan.

I want, however, to impress upon you that any plan, no matter how good, if not diplomatically and persistently worked at will not bring success. To borrow a saying of our production manager, Mr. Kelley, "Success is bought only at the price of eternal vigilance and is never self perpetuating."

How did we get our plan under way? At the beginning, to prevent resentment and antagonism, the records were not displayed, in fact, they were sort of secret. A record of several patterns that were running with an excessive loss was made and quietly given to the instructor who had charge of the molders making the jobs. The next step was a form on which was recorded the records of two instructors, each instructor having molders working the same patterns. A carbon copy of this sheet was given to the foundry superintendent, to the general foreman, and, of course, to each instructor. This would naturally tend to start competition between the instructors concerned. So far no public display had been made. After this plan had been worked for a comparatively short time, commendable results in the reduction of the scrap loss began to be seen; therefore it was comparatively easy to take the next step, that of public display of the performance of all the molders, which, when summed up in groups, gave the group or instructor's loss. This gave us competition not only between the instructors but also between the molders. In addition to this, the weekly loss of the whole foundry as posted was an incentive for making progress by inciting a desire to make each week better than the one preceding.

From then on innumerable things or stunts were schemed out to get attention attracted to this exhibition. As the records were prominently displayed, no one could go through the foundry

without seeing them. Foremen, workers and others from all departments were urged to give the exhibits at least cursory attention whenever possible. No urging was necessary to get the technical department's attention on this. They did many things to reduce the losses which possibly they would eventually have done anyway, but this method of display and follow-up was freely conceded to be of much help.

To keep the manufacturing superintendent in close contact with the excessive losses occurring in the malleable foundry by indicating to him the patterns that are causing these excessive losses the card shown in Fig. 6 was designed. When the stenographer figures the percentages on the daily sheets one of these cards is made up for every pattern showing a loss of nine per cent or greater.

For about an hour and a half on Saturday morning a "Scrap Meeting" is held in the manufacturing superintendent's office, at which are present, the manufacturing superintendent, the foundry superintendent, the general foreman of the foundry, the four instructors, the general foreman of the soft iron department, the general foreman of the core department, the general foreman of the pattern shop, and a representative from the technical department.

At this meeting the scrap situation in general is discussed, but special attention is given to the nine per cent cards. Each instructor is asked to give reasons why his molders made the high loss as recorded on the cards and what steps he has taken to prevent the specific loss in the future. His statements are recorded for future reference. We are very careful to do nothing in a spirit of criticism. It must be kept in mind that the critical attitude on the part of anyone in the meeting is to be avoided.

If the nature of the discussion is such that the instructor feels that he is a vital part of the foundry activities and his ideas will be a main factor in the solution of the problems, not only any originality that he may have will be brought out but it will tend to promote a desire on his part to seek knowledge on these problems which will not only be to his own benefit but to the benefit of others as well.

Due to the fact that the instructor is very close to the actual molding problems it would only be natural for him to have numer-

ous ideas and helpful suggestions in the solution of these problems, especially if we can incite a desire on his part to use the information that is available in the Technical Department as well as from other sources. If, however, he senses a tendency of criticism on the part of any of those present he will naturally be thinking of a defense and it will be hard for him to freely express any constructive suggestions.

Castings that are giving trouble, the disease of which apparently resists all attempts to cure, are brought to this meeting. Some of the castings are broken to show shrink, cracks, and various other defects. A discussion is started and different opinions are given, and from all this discussion a method of procedure is planned which is turned over to someone to follow and report upon at the next meeting. Considerable attention is given to gating. Much thought is given to the ratio of gates, sprues and risers to that of the castings. We try to get these various subjects before the meeting in such a manner as to produce a desire upon the part of the workers to a further study and investigation of all the problems coming up in the foundry.

While this meeting is essentially a "Scrap Meeting" and much attention is given to the nine per cent cards, furnace practice, sand control and reclamation, flask equipment, molding practice, gating problems and metallurgical subjects are freely discussed.

A record of the discussions, decisions, conversations and recommendations is made, and when written up on the following Monday a carbon copy is forwarded to each person that attended the meeting. A very great benefit derived from these meetings is the information, teamwork and cooperative spirit that this "Get Together" seems to promote, all of which is surely conducive to an incentive to "Beat the Record" and produce quality castings with a low loss.

There are many problems in a foundry besides scrap. No one can deny, however, that a foundry with a high scrap loss is not being run as efficiently as one with a low loss. The things that are necessary to do to reduce the scrap tend to wipe out the other problems.

Automatic Blast Gate Control for Cupolas

By H. V. Crawford,* Schenectady, N. Y.

General

To get the best possible results in the melting operation in a foundry cupola, the foundryman should be able to control all of the variables. The three chief variables are the iron, coke and air. The first two can be regulated very readily, but the air has not heretofore been easy to control. Furthermore, the fact that it should be controlled closely has not been generally appreciated.

The proper control of the air entering the cupola and its union with the fuel will prevent many difficulties, such as burnt, cold and spongy iron. Considerable care is generally taken to measure and record the amount of iron and coke charged, but hitherto it has not been possible to measure or weigh the amount of air.

The coke is charged by weight and approximately 80 per cent should fulfil the purpose for which it is used. Approximately 8 per cent is lost on account of the inefficiency of the melting operation and 12 per cent, in the form of ash, is blown out the top of the stack or combines with other impurities to form slag. The iron is charged by weight and eventually flows out of the spout, except for impurities, the percentage of which depends on the nature of the charge. The air also should be charged by

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weight—not by volume. Only 23 per cent of standard air is oxygen; therefore, only this portion fulfils the purpose for which it is introduced, and the other 77 per cent works against the melting operation. The total weight of air used during any heat is more than the combined weight of coke and iron, which fact emphasizes the importance of air control.

In many cases, the object of the foundryman has been to be sure to get plenty of air, and in order to make certain of this, he plans to have some excess for any condition, even if it means a very appreciable excess of some other condition. It will be shown that this is not a proper procedure, however, because an excess of air is worse than a deficiency, since the iron, in addition to being cooled, may be burnt.

The purpose of this paper is to describe an automatic blast gate control for cupolas, developed by the General Electric Company. Before describing this apparatus, it will be necessary to show why the air should be controlled. It will, therefore, be necessary to emphasize a number of fundamental facts.

Melting Zone

Every melting operation requires the application of heat obtained from some form of carbon, combining at the proper temperature with sufficient oxygen and forming carbon dioxide gas. In order to obtain the maximum benefits from this union in the form of heat, the parts to be melted should be as close as possible to the point where the union takes place. In the cupola this is the melting zone and its location is therefore of the utmost importance. The coke bed establishes the melting zone and it should therefore be at such a height that when the proper amount of air is admitted the oxygen in the air will combine with the carbon in the incandescent coke and form carbon dioxide just under the first charge of iron. The succeeding charges of iron should be of the same weight as the first, and the charges of coke should be just enough to replenish the bed and maintain the melting zone at the same position.

The importance of securing and maintaining a proper combination of carbon and oxygen just at the melting zone is shown by the fact that carbon, when burned completely to carbon dioxide, gives off about 14,500 B. T. U. per pound, while carbon burned

to carbon monoxide gives only 4,450 B. T. U. This represents a loss of about 10,000 B. T. U., due to imperfect combustion.

Amount of Air Required

Theoretically, a pound of pure carbon requires 2.66 pounds of oxygen for complete combustion. Therefore, in order to burn a pound of carbon 11.517 pounds of standard air are required. This value is obtained by dividing 2.66 by 0.231, the latter figure being the amount of oxygen contained in a pound of air at standard conditions. One cubic foot of air at 60 degrees Fahr. and 14.7 pounds barometric pressure, with an average amount of moisture, weighs 0.0765 pounds, so that this gives 150 cubic feet of air required to burn one pound of pure carbon.

Assuming a 10:1 fuel ratio (not including the bed, as an amount of coke is usually left at the end of the heat corresponding to the original bed, and it should therefore not be figured in the calculations), one ton of iron requires 200 pounds of coke for melting, and, therefore 30,000 cubic feet of air is required to melt one ton of iron. This has been the basis for a great many years for determining the amount of air required and its use has been accepted so generally as the basis that in a great number of cases the ratio is neglected and the volume is figured on this basis, even though the amount of coke or carbon may be very much higher. In a large number of cases cupolas are operated with ratios as low as 4 or 5 to 1.

It should be remembered, however, that coke is not pure carbon, so taking this into account and figuring that good coke has about 88 per cent fixed carbon, only 88 per cent of the 150 cubic feet, or 132 cubic feet, is required to burn a pound of coke. Therefore, instead of 30,000 cubic feet being required per ton of iron, only 26,400 cubic feet is required.

This amount is reduced further, due to the fact that even if the proper combination of oxygen and carbon may have taken place in the melting zone and carbon dioxide is formed, this gas in passing through the upper layers of coke takes up some of the carbon and therefore the amount of oxygen required in the melting zone is further reduced.

The amount of carbon taken up by the carbon dioxide may

be as high as $\frac{1}{3}$ of the carbon in every pound of coke, so that only $\frac{2}{3}$ of the carbon will require $\frac{2}{3} \times .88 \times 150$ or 88.0 cubic feet of air. In forming carbon monoxide, only one-half of the amount of oxygen is required, so that the other $\frac{1}{3}$ of the carbon will require one-half of 150 or 75 cubic feet. Therefore, $\frac{1}{3} \times .88 \times 75 = 22$. We then have for good practice the amount of air required to burn each pound of coke equaling $88 + 22$ or 110 cubic feet per pound of coke, or $110 \times 200 = 22{,}000$ cubic feet of air required to melt a ton of iron, instead of the usual figure of 30,000 cubic feet.

The above figure does not allow anything for leakage, as with the proper installation the leakage should be confined to that escaping through the slag hole, as the pipe should be so installed, the cupola properly formed, and the proper construction of blast gate used to eliminate any possibility of air leaking. It is impossible to figure correctly the leakage through the slag hole, as this varies during the heat. Also, this does not allow anything for air traveling up the sides of the cupola, but this will be almost negligible if the tuyeres are of the proper height to give the proper velocity to the air so that it will travel further into the center.

Some margin, of course, should be allowed and figuring, therefore, approximately 120 cubic feet of standard air per pound of coke, or 24,000 cubic feet of air per ton of iron, has been found by test to give a sufficient margin.

This has been the basis of recommendations on certain types of blowers for years and it is has been proved by actual practice to be a very good basis from which to work in figuring the volume of air required under normal conditions of 60 degrees Fahr. and 14.7 barometer.

Figuring on this basis for a 10:1 ratio, 24,000 cubic feet per ton of iron is all that is required instead of 30,000. If the latter figure is used 25 per cent too much air or 25 per cent too much oxygen is introduced to exist as free oxygen and oxidize the iron. Also, 25 per cent more inert gas is introduced to help retard the melting operation. More coke can be added but this decreases the ratio and slows up the melting rate.

Blowers are rated in terms of cubic feet of air per minute at 60 degrees Fahr. and 14.7 barometer, and on the basis of approximately 120 cubic feet at 60 degrees Fahr. and 14.7 barometer re-

quired for each pound of coke burned, the following formula can be used.

$$\frac{120 \times 2000 \times T}{60 \times R} = \text{the cubic feet per minute required.}$$

This makes it possible to select the proper size blower. In this formula T equals the tons of iron per hour, R equals the ratio of iron to coke, not including the bed. This formula will reduce to $\frac{4000 \times T}{R}$ which is very simple and easy to remember.

In arriving at a value of R, which is the ratio of iron to coke, it is found that in a large number of cases this is figured on the basis of the total amount of iron charged divided by the total amount of coke charged including the bed, and in other cases the total iron divided by the amount of coke exclusive of the bed. The latter method is more nearly correct, as the amount of coke left unburned is approximately equal to the amount of the original coke bed less the amount burnt in melting the last charge of iron.

Constant Weight Not Constant Volume

The previous calculations have been based on the weight of air at standard conditions of 14.7 and 60 degrees Fahr., but conditions are not always standard, as the air temperature will vary from below zero to 100 degrees Fahr. in certain localities. The barometer will also vary and in some locations, on account of the altitude, will be very low. The weight of a certain volume of air will, therefore, change with the temperature and barometer and therefore blowers should be operated to give, not constant volume, but constant weight.

Using the previous calculations as a basis to start from and figuring that the weight of a cubic foot of air varies directly with the barometric pressure and inversely with the absolute temperature, the volume required at various temperatures and barometric pressures can be determined. A blower that can be operated to give a varying volume between minimum and maxi-

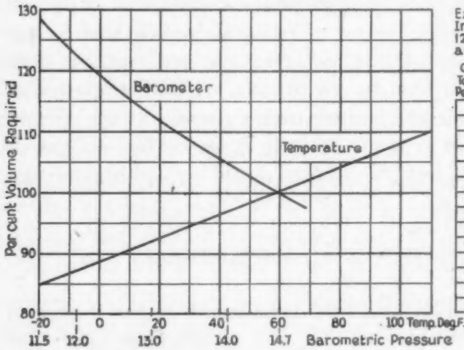
mum requirements and maintain the weight of air constant should therefore be used.

The variation in volume to give constant weight for varying atmospheric conditions is shown in Fig. 1.

Effect of Temperature

For example, in the summer time, with the temperature at 100 degrees Fahr. and atmospheric pressure at 14.7, the volume

Volume of Air Required at Various Temperatures and Barometric Pressures
For
A Constant Amount of Oxygen
Standard Conditions 60°F. and 14.7 Barometer



Example for Cupola Blowing
Iron to Coke Ratio 8 to 1 (Less Bed)
120 CFM Per lb. of Coke Burned
at 60° F. and 14.7 Barometer.

Cap. Tons Per Hr.	Cubic Feet Per Minute			
	0°F. 14.7 Bar.	60°F. 14.7 Bar.	100°F. 14.7 Bar.	100°F. 12.5 Bar.
1	443	500	537	630
2	885	1000	1080	1280
3	1330	1500	1615	1900
5	2215	2500	2700	3170
6	2660	3000	3230	3800
7	3100	3500	3770	4430
9	3980	4500	4850	5700
10	4420	5000	5380	6320
12	5300	6000	6460	7600
14	6200	7000	7550	8860
18	7950	9000	9700	11400
21	9300	10500	11300	13300
24	10600	12000	12900	15200
27	12000	13500	14500	17000

FIG. 1—VOLUME OF AIR REQUIRED AT VARIOUS TEMPERATURES AND BAROMETRIC PRESSURES FOR A CONSTANT WEIGHT OF OXYGEN. STANDARD CONDITIONS OF 60° FAHR. AND 14.7 BAROMETER

figured at 60 degrees Fahr. and 14.7 will expand in the ratio of the absolute temperatures, or $\frac{460 + 100}{460 + 60} = 1.075$. Therefore, in order to get the original weight of oxygen figured, the volume of air should be increased 7.5 per cent. Otherwise, if constant volume is maintained, there will not be enough oxygen for proper combustion. In the winter time, or at zero degrees, the volume figured at 60 degrees will contract in the ratio of $\frac{460}{520} = 0.885$.

Therefore, in order to get the original weight of oxygen figured, the volume of air should be reduced 11.5 per cent.

Figuring, therefore, on the basis of 120 cubic feet, or 24,000 cubic feet per ton of iron at 60 degrees, at zero degrees this volume should be 0.885 × 120 or 106 cubic feet, or 21,200 cubic feet per ton of iron. At 100 degrees, the volume should be 1.075 × 120, or 129 cubic feet per pound of coke burned, or 25,800 cubic feet per ton of iron. This means an increase from zero degrees to 100 degrees or 22 per cent in the volume.

Effect of Barometer

The previous paragraph does not take into account the variation in barometer which at sea-level will be a maximum of 7 per cent, or from 15.2 to 14.2 pounds (31 to 29 inches Hg). The maximum variation in volume will therefore be from zero degrees at 15.2 barometer to 100 degrees at 14.2 barometer. The 106 cubic feet previously figured at zero degrees will, therefore, be reduced in the ratio of $\frac{14.7}{15.2}$, or to 102.5 cubic feet (20,500 cubic feet per ton of iron) and the 129 cubic feet at 100 degrees will be increased in the ratio of $\frac{14.7}{14.2}$, or to 133.5 cubic feet. This means, therefore, an extreme variation in volume from 102.5 to 133.5 or 30 per cent.

Effect of Humidity

Under ordinary circumstances, the air handled by a cupola blower will carry a small amount of water vapor. If, however, due to changes in the weather this humidity of the atmosphere changes, there will be a change in the density of the air which will involve a change in the per cent of oxygen constant. Due to this effect, there will be an error at one extreme when no water vapor is present at all, of 0.3 of 1 per cent and at the other extreme on a very hot, humid day, of 1.5 per cent. This gives a range between no humidity and maximum humidity of nearly 2 per cent.

In the previous paragraphs, the minimum requirement in volume has been figured at 0 degrees and 15.2 barometer pressure as 102.5 cubic feet per pound of coke, or 20,500 cubic feet per ton of iron. Taking into account humidity for the minimum volume, this would be at the extreme where no water vapor is present, and the 0.3 of 1 per cent would have no appreciable effect on the above values.

Total Effect

The above figures show that a very serious error is made when the air required is figured on the old basis of 150 cubic feet of air per pound of coke, or 30,000 cubic feet per ton of iron for all conditions of the intake air. At the minimum condition of 0 degrees, 15.2 barometer, and no humidity, the excess air or oxygen will be the difference between 30,000 and 20,500 cubic feet, or 46.5 per cent.

It follows that if we had some perfect means of supplying a cupola with a constant volume of air, and if this volume were exactly correct at one extreme, it would be very seriously in error at the other extreme. Certain types of blowers, and certain types of air meters have been developed, with the idea of securing this constant volume. However, even the most perfect operation of these machines and meters will give the serious discrepancies illustrated at one extreme or the other.

Effect of Excess Oxygen

For perfect combustion a definite weight of oxygen should combine with a definite weight of carbon in the coke to give carbon dioxide gas in the melting zone so that if too much oxygen is supplied free oxygen will exist and combine with the iron in the melting zone and the result is oxidized or burnt iron. Also the excess oxygen carries more nitrogen and this increases the cooling action so that the iron is not only burnt, but is cold. Twenty-three per cent of the air is oxygen, which is the agent promoting combustion, and the other 77 per cent is largely nitrogen and inert gas which is heated to the maximum temperature in the cupola and then discharges into the atmosphere having done but very little work. As it passes through the successive layers

of iron and coke it gives up some heat but it travels at such a high velocity it has sufficient time to give up only a small percentage of this heat.

Excess oxygen, therefore, means not only oxidized iron but the iron is cold and spongy.

Effect of Insufficient Oxygen

Insufficient oxygen means that the oxygen is all consumed in combining with the coke in the lower part of the layer of coke just at the melting zone. Carbon dioxide is formed but of an insufficient amount and also it encounters the incandescent coke in the upper part of the layer of coke just under the melting iron and is converted into carbon monoxide gas. This occurs in the regions just where the highest temperature to be secured by forming carbon dioxide is required. The result is cold iron and slow melting with the possibility of bridges forming.

Effects of Pressure

Before discussing the proper method of control, possibly reference should be made to the part the air pressure plays in the melting operation. In some cases the practice has been to hold constant pressure on the wind box, but holding constant pressure is entirely wrong as the resistance to the flow of air through the cupola will vary and, therefore, the pressure on the wind box should vary. Also the volume will vary according to varying temperature and barometer and the pressure on the wind box must be increased to force a greater volume through the cupola. Pressure, therefore, does not bear any relation to the operation other than being the agent for forcing the proper amount of air or oxygen into the cupola. However, it is well to remember that for large size cupolas additional pressure must be available in order to force the air through the tuyeres at a greater velocity and therefore carry them into the center of the cupola and to overcome greater cupola resistance due to the higher charging doors. If a cold spot is forming in the center, this means that the air is passing up around the side and is not penetrating to the center and, therefore, the height of the tuyeres should be cut down. Then, of course, the higher pressure is required to force

the same amount of air through the effective area, and this increases the velocity of the air and it penetrates further into the cupola.

Method of Control

Since the best results in the melting operation depend on having the weight of air, iron and coke under complete control, the next step is to introduce an apparatus and a method of controlling the weight of air supplied to the cupola. Obviously, the resistance to flow of air through a cupola varies from minute to minute with the constantly changing conditions.

The company with which the writer is connected has developed a certain electrical control system which is connected with the line supplying current to an electric motor operating a centrifugal compressor with characteristics suitable for this purpose. This control operates an artificial restriction, placed in the pipe between the blower and the cupola. This compensates for changes in cupola restriction, as well as for changes in atmospheric conditions, so as to maintain a constant weight of air flowing at all times. The mathematical theory of the operation of this apparatus is fully explained in Appendix I. It is there demonstrated that any change in the resistance to flow through the cupola, or any change in the atmospheric temperature or pressure, is automatically compensated for, so as to maintain the same weight of air per minute, regardless of the changes mentioned.

Control Equipment

The electrical control system previously mentioned operates on the principle demonstrated mathematically in Appendix I, that a blower and motor of suitable type have such characteristics that constant weight of air is delivered when the electrical input in kilowatts is maintained constant. The apparatus consists of a blast gate which supplies an artificial restriction in the line, which is so manipulated as to give the motor input the desired constant value. This manipulation may be done by hand on the basis of use of an ordinary watt meter, Fig. 2, and hand blast gate, Fig. 3, or it may be done automatically by a mechanism described later and thereby eliminate the personal equation.

As has been stated, the apparatus is to be actuated primarily by the power input to the motor. However, in ordinary cases, voltage is fairly constant, so that the current reading in amperes varies directly with the kilowatts input. This ampere reading

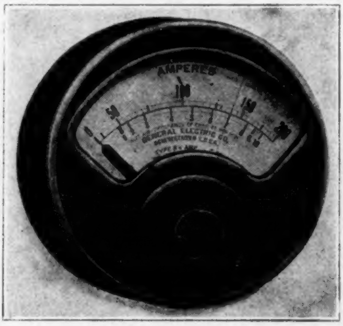


FIG. 2—METER CALIBRATED IN POUNDS OF AIR PER MINUTE

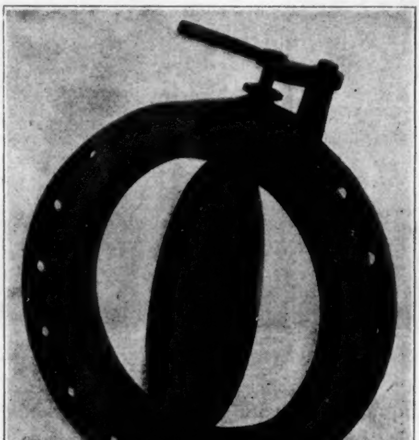


FIG. 3—HAND-OPERATED BLAST GATE

may therefore be used in most cases instead of the kilowatt reading.

The automatic control equipment, Fig. 4, consists of a reversing motor geared to a blast gate, and with a large gear ratio and provided with limit switches to prevent the gate from overtraveling and jamming. The control panel mounts an ordinary

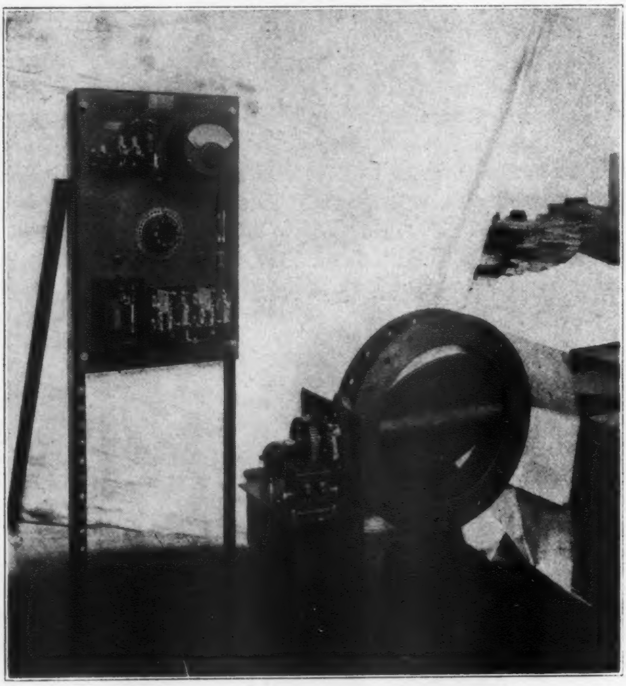


FIG. 4—AUTOMATIC GATE AND CONTROL PANEL

contact making ammeter with an indicating ammeter calibrated in pounds of air, switch and fuse, regulating rheostat and three standard contactors.

When the current increases slightly, contact is made and the circuit is completed through one of the contactor coils. The

contactor closes and supplies power to the small motor rated at approximately $\frac{1}{16}$ h.p., causing it to run in the proper direction to close the blast gate, bringing the current down to normal again. Likewise, when the current falls slightly, the other contactor closes, running the motor in the other direction, thereby opening the gate and bringing the current up to normal again.

The third contactor is energized all the time the blower motor is running, and power for operating the panel is supplied through its contacts. When the blower is shut down at the end of the heat, this contactor drops out and an auxiliary contact closes the power circuit to the panel, so that power flows direct to the closing contactor and the gate moves to the closed position and the limit switch on the gate breaks the circuit. This means that the blast gate is always in the closed position at starting, which gives the best starting condition and also serves to automatically close the gate and prevent the gases from the cupola backing up into the pipe line and compressor casing and thereby eliminates the probability of an explosion.

The rheostat is used to vary the reading of the ammeter so that any desired value of pounds of air can be maintained within the limits of the blower, which is approximately from 20 per cent of normal load to 20 per cent overload. The contact making ammeter arm is adjusted to the horizontal position by screws and a spring and for a given current, corresponding to the normal current on the machine, with the rheostat in approximately mid position and in parallel with the coil on the contact making ammeter the arm will float in this position with both contacts open. If the current or pounds of air value is to be increased, some of the resistance is cut out, allowing more current to flow through the rheostat and less through the current coil. This causes one of the contacts on the arm to close and the blast gate is opened wider, increasing the flow of air. The increased flow of air increases the current to a value which causes the contact to open and the arm returns to the horizontal position. The new value of current and the corresponding new weight of air are indicated on the indicating ammeter. To reduce the weight of air, the rheostat handle is turned in the opposite direction and the resist-

ance increased. This causes the other contact on the arm to close and the gate closes and reduces the weight of air to the lower value required.

The equipment is made of standard parts properly enclosed and requires no attention other than oiling of the small motor and gears probably once or twice a year.

Blower Characteristics

The control equipment just described is only suitable for use with blowers having certain characteristics. Fig. 5 shows the characteristics of such a blower, and it can be shown from this figure that constant K.W. input or constant current will give constant weight of air.

Figuring for a certain condition that 7000 cubic feet is required at 60 degrees Fahr. and 14.7 to give the proper weight of oxygen, when the air temperature increases to 100 degrees Fahr. this 7000 cubic feet will expand so that the volume of inlet air should be increased in order to get the same weight of air. The weight of the air will vary inversely with the absolute temperature of the air, so that we have $\frac{560}{520} \times 7000 = 7550$ cubic feet of air to give the same weight of air.. Likewise, when the air temperature drops to 0 degrees Fahr. we have $\frac{460}{520} \times 7000 =$ 6200 cubic feet to give the same weight of air. This shows an increase in the volume from 0 degrees to 100 degrees of 22.0 per cent in order to maintain a constant weight of air.

Referring again to Fig. 5 the K.W. input for 7000 cubic feet for the 60 degree condition is 48. For 6200 at 0 degrees Fahr. the K.W. input is also 48 and also at 7550 cubic feet at 100 degrees Fahr., the K.W. input is 48.

This shows conclusively that holding a constant K.W. on a machine having characteristics of this nature, a constant weight of air will be delivered irrespective of changes in temperature, barometer or altitude, or resistance through the cupola.

Results Obtained

As a proof of the fact that this equipment will hold a constant weight of air for varying conditions, tests have been made with recording instruments, but unfortunately these were not started in time to show any appreciable change in temperature, but by the time this paper is presented, it may be possible to supplement

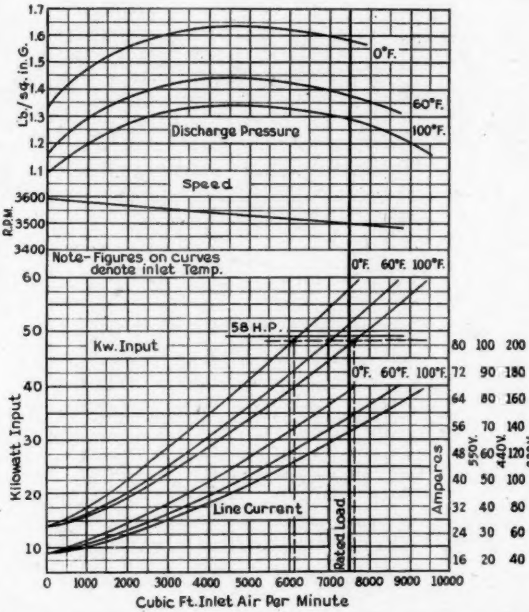


FIG. 5—CHARACTERISTIC CURVES OF CENTRIFUGAL COMPRESSOR RATED AT 7500 CUBIC FEET PER MINUTE, 1.25 POUND PER SQUARE INCH BASED ON AIR AT 14.7 POUND PER SQUARE INCH ABSOLUTE; MOTOR 3-PHASE 60 CYCLES, 220/440/550 VOLTS

it with more curves showing for a given weight the variation in volume due to temperature changes. Practical results through eight months' operation, however, have unquestionably proved the worth of this equipment.

Fig. 6, 7 and 8 show results on three consecutive days when

the temperature was practically constant, and Fig. 9, 10, 11 and 12 show the actual charts for one day. The curves in Fig. 6, 7 and 8 were plotted from the actual charts.

These tests were made on a d.c. installation and the slight variations are due to voltage change. Supplemental information

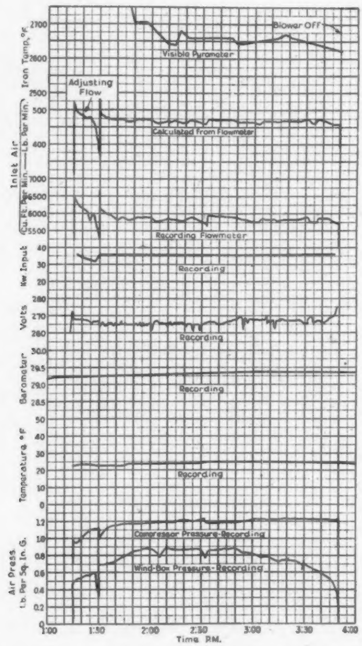


FIG. 6—TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA

will be on the basis of tests on an a. c. equipment, where the voltage will be practically constant.

The upper curve in Figs. 6, 7 and 8 shows the iron temperature taken with an optical pyrometer. The consistently high temperature of the iron for the three consecutive days should be noted. This is, of course, the result desired and once the proper

combination of pounds of coke, iron and air is determined it can be maintained day in and day out and consistent results will be obtained.

There is nothing to wear on the blower, motor driven blast gate, or control, so that the weight of air will be maintained at

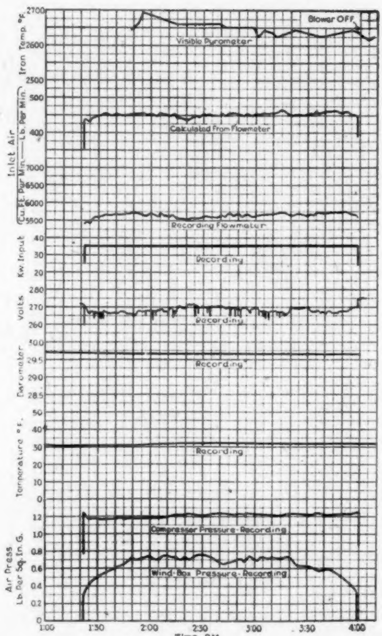


FIG. 7—TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA

all times and within close limit, and this factor which has been so hard to determine and control in the past is now automatically controlled and all the attention can be given to maintaining the coke and iron of the proper relation.

When a change is made in the lining diameter of the cupola the weight of air can be changed to suit the new operating condi-

tions and, likewise, if a different kind of coke having more or less fixed carbon is used the weight of air can easily be figured and the equipment reset to give this amount and the best operating conditions again secured.

During any certain run if it is felt that more or less pounds

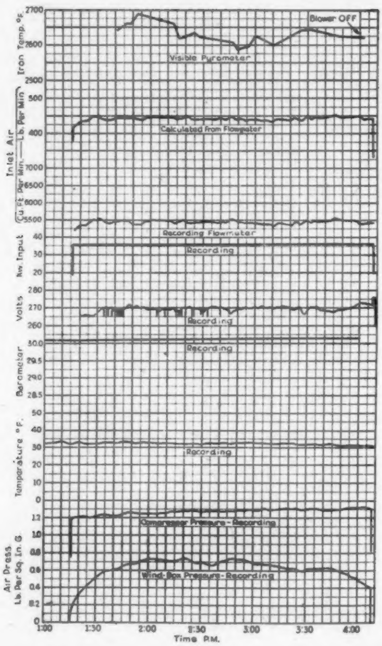


FIG. 8—TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA

of air is required immediately the equipment can be set in a few seconds to increase or decrease the weight of air as required.

The equipment furnished so far is shown in Fig. 4, but additional features can be added such as enclosing case, with lock to prevent anyone but an authorized person tampering with the control, auxiliary meter located at cupola indicating readily the

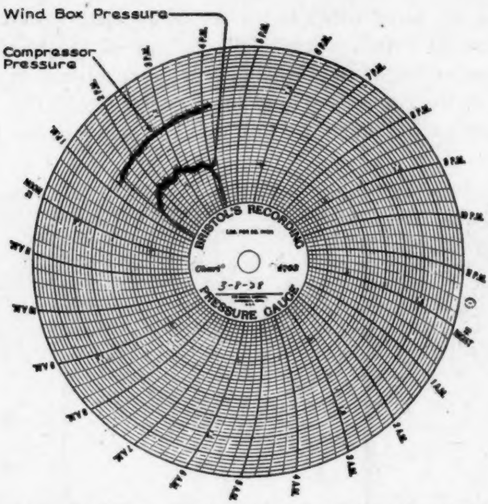


FIG. 9—ACTUAL CHART OF TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA

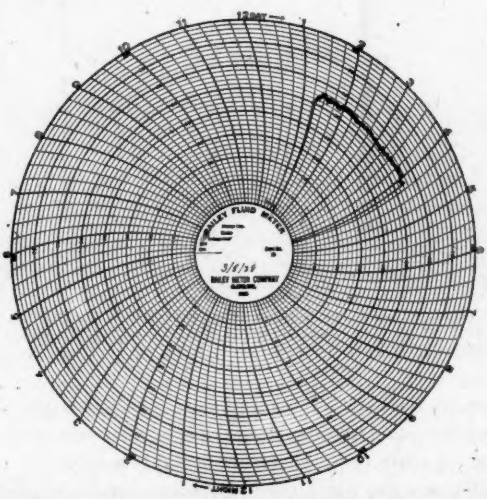


FIG. 10—ACTUAL CHART OF TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA. INLET VOLUME 200 CUBIC FEET PER MINUTE PER DIVISION

weight of air being used, and a recording meter located on the panel or at the cupola to give daily records of weight of air. A two-pen recording pressure gauge can be furnished showing the pressure at the compressor and in the wind box. This provides a chart similar to that shown in Fig. 9 and indicates the difference

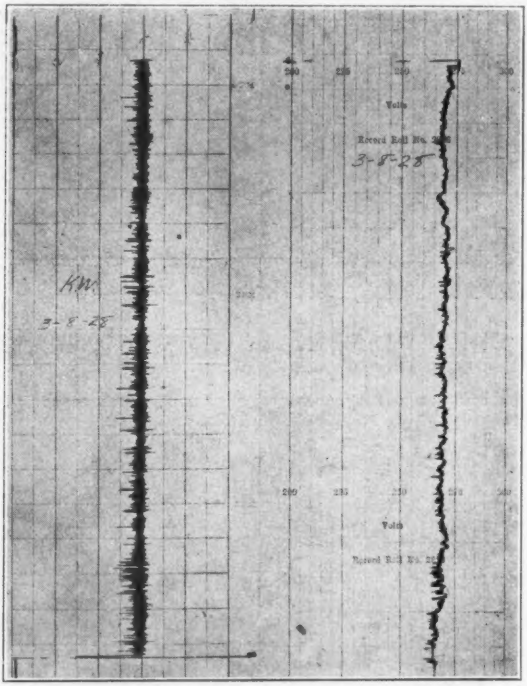


FIG. 11—ACTUAL CHART OF TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA. K.W. INPUT AND VOLTAGE

in pressure on the sides of the gate. If the curves are very close, this shows that the tuyeres should be broken out with a bar to reduce the pressure required on the wind box side.

In all cases the parts used are simple and of standard construction and will give indefinite service.

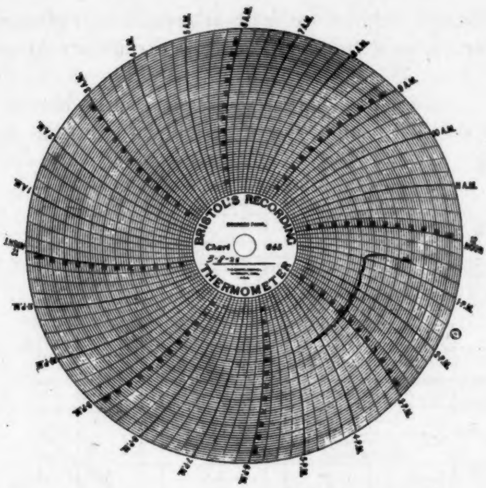


FIG. 12—ACTUAL CHART OF TESTS ON CENTRIFUGAL CUPOLA BLOWER WITH AUTOMATIC CONTROL HOLDING CONSTANT WEIGHT OF AIR DELIVERED TO CUPOLA. INLET AIR TEMPERATURE °F.

APPENDIX I

Mathematical Theory of the General Electric Company Automatic Cupola Control

As has been stated, certain centrifugal compressors or blowers, driven by substantially constant speed motors, have characteristics such that within the range of normal operation the effect of increase of volume on the electric power input and the effect of atmospheric conditions on the power input is such that the power input varies only with the weight of air. This weight is found by multiplying any existing volume by any existing density due to any existing atmospheric conditions. Such a compressor gives a given power input for a given product of volume times density, regardless of the individual values of these two factors. With such a motor-driven centrifugal compressor, the power input varies in the same ratio as the weight of air. Therefore, if operated at constant K.W. input, the weight of air will

be held constant within close limits irrespective of changes in the atmospheric temperature, barometer or resistance through the cupola.

Fig. 13 shows the characteristics of such a blower and referring to the K.W. input curve, it will be seen that a straight

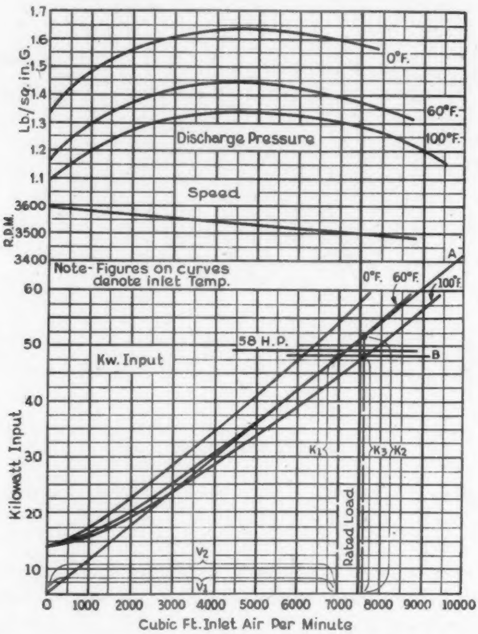


FIG. 13—CHARACTERISTIC CURVES OF CENTRIFUGAL COMPRESSOR RATED AT 7500 CUBIC FEET PER MINUTE, 1.25 POUND PER SQUARE INCH BASED ON AIR AT 14.7 POUND PER SQUARE INCH ABSOLUTE; MOTOR, 3-PHASE, 60 CYCLES, 220/440/550 VOLTS. ILLUSTRATING PROOF OF MATHEMATICAL THEORY.

line "A" can be drawn which is practically coincident with this curve and passing through the origin. With a curve of this shape, it is definitely proved below that this machine will deliver a definite weight of air per unit time for each reading of wattmeter, regardless of atmospheric temperature, barometer or altitude.

Assuming for one condition a power input K_1 and a flow of cubic feet of air V_1 and a value of inlet density D_1 (at 60° Fahr.) and a second condition where the values are K_2 and V_2 and the density is the same as the original density D_1. Then, since the power curve in the region in which we are working practically coincides with a straight line through the origin, we will have—

$$\frac{K_2}{K_1} = \frac{V_2}{V_1}$$

Suppose now that at the second point the density is not the original value D_1, but has another value D_3 (at 100° Fahr.) such that the weight of air passing through the machine will be the same as the weight at the original point where the inlet volume is V_1. With constant weight, density and volume are inversely proportional, hence,

$$\frac{V_1}{V_2} = \frac{D_3}{D_1}$$

The power at the second condition when the density was D_1 had the value of K_2. If, however, the density is D_3, the power K_3 will vary directly as the density. Hence,

$$\frac{K_3}{K_2} = \frac{D_3}{D_1}$$

This is true, regardless of the efficiency or shape of efficiency curve, since we are working at a given value of inlet volume and hence at a given efficiency. It follows from the last two equations that

$$\frac{K_3}{K_2} = \frac{V_1}{V_2}$$

From the first equation, it follows that

$$\frac{K_2}{K_1} = \frac{K_2}{K_3}$$

Hence,

$$K_1 = K_3$$

Referring again to Fig. 13, $V_1 = 7000$ cubic feet and $K_1 =$ 48 K.W. and D_1 is the density at 14.7 barometer and 60 degrees Fahr. temperature. At the second condition, if D_3 is the density

at 14.7 barometer and 100 degrees Fahr. in order to hold constant weight, the volume will increase in the ratio of absolute temperatures, as the change in density is due to the change in temperature from 60 to 100 degrees Fahr.

$$\frac{460 + 100}{460 + 60} \times 7000 = 7550 \text{ CFM}$$

Therefore at 7550 CFM at 100 degrees K_3 also equals 48 KW or a horizontal line "B" can be drawn through the points where V_1 crosses the 60 degree input curve and V_2 the 100 degree curve.

It follows, therefore, that an iron foundry cupola may be provided with a constant weight of air at all times by manipulating the blast gate or throttle valve in the discharge line. The cupola pressure will vary from time to time and it is therefore necessary in laying out a blower for an iron foundry cupola, to arrange the pressure slightly higher than would be needed for average operation, and to throttle the difference with the blast gate. Then if atmospheric conditions, density of the coke or iron, changed conditions of the tuyere, or anything else tends to increase or decrease the weight of air supply so as to change the wattmeter reading, the flow can be restored by manipulation of the blast gate.

Varying the opening of the blast gate simply inserts or removes restriction to the flow of air and this restriction being in series with the natural restriction through the cupola, the gate closes to add restriction when the cupola restriction drops or opens to remove the restriction as the cupola restriction increases, thereby maintaining a definite restriction in the system, so that a certain volume corresponding to a certain weight will only flow for a given condition. If the conditions of temperature or barometer change, the blast gate assumes a certain position to let the proper volume of air flow, corresponding to the same weight of air, and this position is maintained until the restriction through the cupola increases or decreases, and it will then change again to maintain this volume constant for this condition.

Reducing New Sand Consumption in the Steel Foundry

By H. A. Mason,* Depew, N. Y.

Molding sand has been a big problem in the foundry industry since the first casting was cast in sand. Molders of the past generation did well because they had plenty of time to take care of their sand, this being a large part of their job. Production was slow, sand was cheap, and a great deal of time was given over to the preparation of sand for use in the foundry.

As the years advanced, new problems came up through the advent of high speed production and the increase in cost of new sand. The last mentioned problem particularly affected plants far removed from a sand bank. High speed production in the foundry eliminated the preparing of the sand by the molder and passed this work on to a department which in most large steel plants does nothing but prepare facing and heap sands for use in the foundry.

Through the development of mechanical sand handling devices and the tremendous strides made in sand quality control, the sand preparing department has kept pace with high speed production in the foundry by delivering the quantity of sand desired to any particular molding floor and this sand, in the case

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of most foundries, is more uniform and of a better quality than that prepared by the molder in the old days when half his time was given over to the preparation of his sand.

Having solved the problem of delivering sand to the foundry continuously and in large quantities, and at the standard of quality demanded by the foundry foreman, attention was turned to the fact that molding costs were mounting due to the increase in the cost of new sand.

During the past few years much has been written on the subject of economy and reclamation of steel foundry sands and many tests have been carried out by eminent engineers and foundry experts. The field, therefore, is not a new one but one which has generally been neglected by the men in the foundry, core room, and on the sand mills, who actually use the sand and to whom careful investigation of the use of reclaimed sand should serve the most as reflected in greater operating efficiency and consequently lower costs in their respective departments.

It is with the method employed by the Gould Coupler Company, with which company the writer is connected, to reduce the new sand consumption in the foundry and core room and consequently lower molding and core costs, that this paper will deal.

Earlier Practice

As is the case in most steel foundries, our former practice in regard to new sand was to use as much as was thought necessary to insure castings free from defects and of good appearance. A fairly thick layer of new sand facing was placed next to all patterns and this facing sand was backed up with well prepared heap sand. This method, of course, gave uniformly good results, the defective work was low and the appearance of the castings was above the average.

In the core room a great majority of the cores were faced with new sand and good results were obtained from this source of so many of the troubles encountered in the foundry. On the other hand, the new sand consumption in pounds per net ton of good castings was high and the money spent for new sand and the removal of waste sand from the shop, over the period of a

year, ran into a tremendous amount. It was plainly apparent that a reduction in the amount of new sand used in the shop would result in a considerable saving in operating costs. The problem was to select a method of accomplishing this reduction which would have the greatest chance of success.

Analysis of Use of Sand

An analysis of the use of new sand in the foundry and the core room revealed that the bulk of the new sand consumed was used in new sand facing for both molds and cores, and in the large amounts of new sand added to the heap sand pile to increase the permeability of this sand.

Our problem of reducing new sand consumption consisted, therefore, of two parts:

1. That of providing a sand which would give as good results as new sand facing.

2. That of providing a heap sand which will not close up and require the addition of new sand to open it up or raise the permeability.

Facing

Attacking the first part of the problem, it was realized that the sand in a mold, especially that portion of the sand next to the casting, is subjected to very severe usage. Due to the intense heat of the molten steel, which sets up tremendous stresses in the individual grains of sand, these are split up into smaller particles. The bonding materials, such as clay, and manufactured bonds, are also affected by the high temperature. The clay nearest the casting is burned out or dehydrated and loses its plasticity and in this state is useless for rebonding. If used in subsequent sand mixtures it only serves to fill up the voids between the particles of sand and in this way decreases the permeability. However, only a small percentage of the total quantity of sand in a mold is directly affected by the intense heat. The major portion of the sand in a mold still retains its original qualities and therefore could be used repeatedly if some means of removing the burned out sand and recovering the good sand could be devised.

Experiments in Sand Reclaiming

Several years ago the Gould Coupler Company began an intensive investigation of methods of sand reclaiming. After experimenting along many different lines and thoroughly going over methods used by other plants manufacturing a similar product, a process embodying the principles of removing the vitrified or split grains of sand by screening and the dehydrated or burned out bonding material by air suction was developed.

The first step in developing the sand reclaiming process took the form of exhaustive durability tests of both sand and clay. These tests were based on the theory that all that is necessary from a practical standpoint in the reclaiming of sand is to remove, in the cheapest manner possible, the vitrified or split grains of sand and the burned out bonding materials which have come in actual or close contact with the hot steel, and having done this, mix the reclaimed sand with a highly refractory durable bonding agent together with that amount of new sand necessary to keep the amount of sand on hand in the foundry constant, until it possesses the necessary properties required for the class of work which is to be done.

The equipment used in the tests consisted of a miniature sand reclaiming unit, a number "O" Simpson sand mixer, and a small sand dryer. Actual conditions encountered in the foundry were simulated as near as possible.

Tests on Clays

Realizing that clay bond would play an important part in any sand reclamation program, preliminary tests were run on several kinds of clay and by the process of elimination all but two of the clays tried were found unfit for our use in this work. The first of these clays, which we will call clay *A* was a comparatively cheap, fat colloidal clay with a fusion point of 2,800 degrees Fahr. The rating of clays by the Bureau of Standards places clay *A* near the top range of average foundry clays. The second clay, which we will call clay *B*, was a comparatively high priced, hard, lean, highly refractory clay with a fusion point of 2,950 degrees Fahr. The fusion points of the two clays, as quoted, were determined by the Mellon Institute of Pittsburgh, Pa.

FIG. 1—SHOWING EQUIPMENT USED IN SAND TESTS. FROM LEFT TO RIGHT: SAND DRYER, MINIATURE SAND RECLAIMER AND NO. 0 SIMPSON SAND MIXER

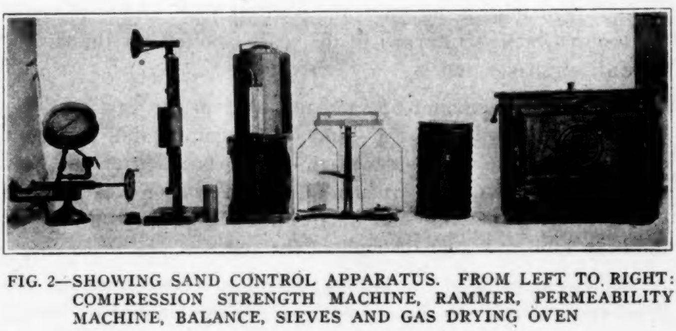

FIG. 2—SHOWING SAND CONTROL APPARATUS. FROM LEFT TO RIGHT: COMPRESSION STRENGTH MACHINE, RAMMER, PERMEABILITY MACHINE, BALANCE, SIEVES AND GAS DRYING OVEN

To determine the relative values of these clays in a process of sand reclaiming, such as contemplated by us, a comparative durability test was made. The results of this test may be of interest to the foundry trade in general.

In running these experiments, the greatest care was taken to obtain accurate and reliable results.

A wood floor was laid in one corner of the shop and this was covered with sheet tin to guard against the introduction of any foreign matter into the sand being tested. Each piece of the equipment used in the test was placed upon this floor.

A small hand flask was used, together with a small pattern requiring no cores. The ratio of the weight of sand in the flask to the weight of the casting was maintained at 8 to 1, which is the approximate average ratio in the day to day practice in our foundry.

A quantity of new Ottawa silica sand was selected and mixed in the sand mixer with the necessary bonding materials until it possessed the physical and chemical properties of our No. 1 new sand facing. A careful check was made of the weight of sand and bonding material used in the first and all subsequent sand mixes, the total weight of the mixture being about 50 per cent above that required for the mold.

The amount of sand necessary for the mold was then rammed up and the mold transferred to the pouring floor. After the mold was poured, it was returned to the space allotted for the experiments and shaken out.

The surplus amount of sand not used in the first mix was thoroughly mixed with the sand cast against and the same amount taken out as representative of the condition of the heap sand after one cast had been made. This operation was repeated on each mix and in this way a careful check of the condition of the heap sand was kept throughout the test.

The remainder of the sand, to save time between mixes, was dried and run through the reclaimer where the vitrified or burned out material in the form of flakes or scales and the dehydrated clay and other bonding material was removed. The good sand, after cooling, was weighed and the loss in weight caused by the

Table 1

Mix No.	Lbs. Clay Used: Clay A	Lbs. Clay Used: Clay B	Strength Facing Sand A	Strength Facing Sand B	Strength Heap Sand A	Strength Heap Sand B	Permeability Facing Sand A	Permeability Facing Sand B	Permeability Heap Sand A	Permeability Heap Sand B	Moisture Facing Sand A	Moisture Facing Sand B	Moisture Heap Sand A	Moisture Heap Sand B
1	55	31	1.1	1.1	1.1	1.1	167	142	167	142	3.1	3.8	4.2	4.0
2	None	None	1.0	1.2	0.9	1.1	156	151	142	146	3.4	3.4	4.4	4.0
3	None	None	1.1	1.0	0.9	1.0	156	173	146	156	3.0	3.2	4.2	3.8
4	4	None	1.0	1.2	0.8	1.0	205	163	138	156	3.0	3.8	3.8	4.2
5	None	None	1.1	1.2	0.9	0.9	146	173	128	151	3.6	3.6	4.0	4.4
6	6	4	1.1	1.0	0.8	0.9	178	173	134	163	3.8	3.6	4.0	4.4
7	6	4	1.1	1.1	0.8	1.0	142	178	126	163	3.7	3.4	4.0	4.2
8	4	4	1.4	1.0	0.8	1.0	167	178	134	167	3.6	4.7	4.4	4.0
9	4	None	1.0	1.2	0.7	0.9	163	156	138	163	4.4	3.7	4.6	4.4
10	6	None	1.2	1.2	0.7	0.9	151	163	138	156	4.4	3.2	4.2	4.0
11	14	4	1.4	1.0	0.6	0.8	193	205	138	151	4.2	3.8	4.0	3.8
12	6	3	1.2	1.1	0.7	0.7	178	193	142	156	3.6	5.0	4.2	3.6
13	6	6	1.3	1.1	0.6	0.9	163	219	134	163	3.6	3.4	4.4	4.2
14	6	4	1.3	1.1	0.6	0.9	212	212	134	167	3.8	3.2	3.8	4.2
15	4	4	1.1	1.0	0.6	0.8	173	219	128	156	4.2	5.0	4.0	4.0
16	4	4	1.2	1.1	0.5	0.8	163	205	128	151	4.2	3.8	4.2	4.4
17	6	2	1.1	1.0	0.4	0.8	178	235	126	151	3.6	3.5	4.4	4.0
18	4	6	1.2	1.0	0.4	0.9	156	185	122	142	3.6	4.0	4.0	4.2
19	4	4	1.0	1.4	0.4	0.9	163	185	122	146	3.8	3.8	4.2	4.2
20	6	4	1.1	1.2	0.3	0.9	185	173	119	146	3.4	4.2	4.2	4.0

removal of the vitrified sand and dust in the reclaiming process was made up by adding new sand.

This mixture, representing our theoretical reclaimed sand facing, was put into the mixer; sufficient moisture was added and after a milling time of six minutes, tests of permeability, strength, and moisture were made. Any decrease in strength below the minimum figure used in facing sand in the foundry was made up through the addition of dry clay to the mixture. After each addition of clay to any one mix, new values of moisture, strength, and permeability were taken.

In the same way, with the exception that the milling time was reduced to three minutes, the permeability, strength, and moisture of the heap sand, as represented by the surplus of sand after each cast, was taken and tabulated for each mix.

This same procedure was repeated over the period of twenty cycles or mixes for each kind of clay, in each mix adding only that amount of new sand needed to make up the loss through the reclaiming operation and recording the permeability, strength and moisture values of both facing and heap sand after each mix.

The condition and appearance of the castings was also watched closely on each succeeding mix and any difference noted. The tabulated results of the test are as given in Table 1.

Analysis of Tests on Clays

A summary of the results as tabulated in Table 1 reveals the following salient points as given in Table 2.

Table 2

Type of Clay	Clay A	Clay B
Number of mixes cast against	20	20
Pounds of clay used	145	85
Average strength (facing sand)	1.1	1.1
Average permeability (facing sand)	164	170
Average moisture (facing sand)	3.7	3.8
Strength of heap sand at end of test	0.3	0.9
Permeability of heap sand at end of test	119	146

An analysis of the summary of Table 2 shows that with our system of reclaiming that we were able to maintain a high permeability in our facing sand, using either clay A or clay B. Therefore, the conclusion is that our principle of reclaiming is

fundamentally sound in that notwithstanding the fact that almost twice the amount of clay A was used over clay B, we were able to remove the inert material and so preserve a good open facing sand.

An analysis of the results in regard to heap sand reveals that our theory, that a highly refractory durable clay is necessary in the success of any comprehensive program of sand reclaiming which has for its object the substantial decrease of new sand consumption, was correct.

As shown in the tabulated results of the test, the permeability and strength of the heap sand using clay A had dropped at the end of the test to 119 and .3 respectively. The drop in permeability and strength of the heap sand would mean that sooner or later the foundry foreman would report that his heap sand was too close and as is the case in a great many steel foundries, a carload or two of new sand would be run into the foundry on Saturday night or Sunday when the cranes are not busy, and unloaded and scattered over the heap sand pile. The addition of new sand, which in our case has practically no bonding strength, to the heap sand pile would mean that the strength of the heap sand would be still further lowered and this fact would call for the addition of clay in the mulling operation of the heap sand, thus increasing the mulling time per batch, which in our case is a vital cog in our scheme of high speed production.

On the other hand, the heap sand taken from mixes using clay B shows permeability and strength values of 146 and .9 respectively. From these results it is apparent that in using clay B as a bonding agent, a smaller amount of dehydrated or inert material is deposited in the heap sand, thus keeping it open, and it naturally follows that if a smaller amount of dehydrated material is deposited, there must be a greater percentage of good plastic bond available for use. This point is apparently proven in the .9 strength value of the heap sand at the conclusion of the test using clay "B."

The castings, at the end of the test using clay B, showed a uniform quality; the sand did not burn in and it peeled readily from the casting, which condition would make for lower cleaning

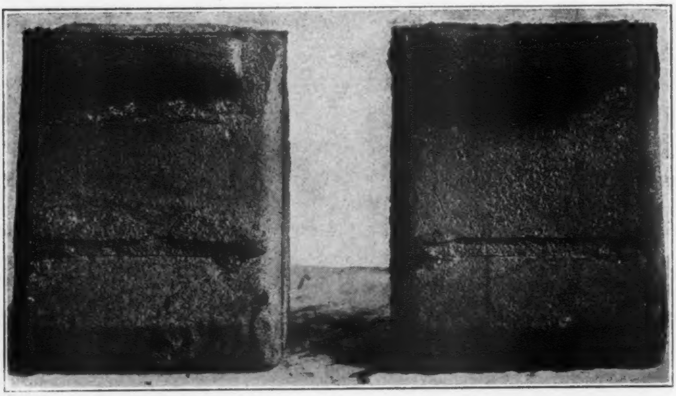

FIG. 3—SHOWING, FROM LEFT TO RIGHT, CASTINGS MADE FROM TWENTIETH SAND MIX USING CLAY A AND CLAY B

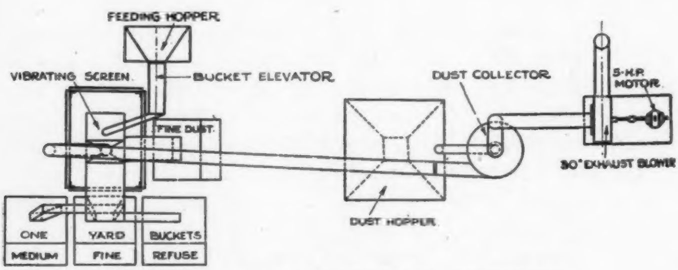

FIG. 4—PLAN VIEW SAND RECLAIMING SYSTEM

costs. In the case of clay A, probably due to a lower vitrification temperature, the castings started to burn in after the twelfth mix and were generally of a rougher appearance than the castings made from mixes using clay B.

According to the results of the tests, we had apparently solved our problems relative to the method to be used in reducing our new sand consumption in the foundry in that through our reclaiming process we would be able to provide a sand which would give as good results as new sand facing and at the same time through the use of a highly refractory durable clay provide a strong, open heap sand which would not require additions of new sand to open it up or clay to maintain its strength. And, in addition, probably the greatest satisfaction was gained from the fact that the test results using clay B indicated that this could be accomplished with no diminution in the quality of the castings. If anything, the castings made in reclaimed sand bonded with clay B looked better than those made using all new sand facing.

Application in Production Work

So much for the laboratory tests. These, of course, mean nothing if the results obtained from them cannot be practically applied to the daily routine in the foundry.

The results gained through this series of experiments at least looked worthy of a trial and with these results as a base upon which to build, a sand reclaimer, capable of turning out one hundred (100) tons of reclaimed sand per twenty-four hours, was built at an initial cost of $3,000.00 This machine was placed on the flogging or trimming floor where the molding sand adhering to the castings and the core sand which is knocked out of the castings by the knockout hammers is readily available. This sand is bucketed and scraped in close proximity to the reclaimer by the overhead crane and from this point is shoveled by hand onto a heavy large mesh screen. This screen serves to remove any rods, wires, nails or steel trimmings which may be in the sand. The sand, free from all metallic substance, is discharged down a chute and empties into a bucket elevator which carries the sand to the top of the reclaimer where it is dumped onto the vibrating screens.

The design of the reclaimer, as in the miniature unit used in the tests, called for the removal of the vitrified or split grains of sand by screening and the burned out bonding materials by air suction.

Three vibrating screens are used in the reclaimer, and these are arranged in triple deck fashion, one on top of the other—all of them being inclined at an angle of about thirty (30) degrees. The top screen, which removes the scale, flakes, and lumps of vitrified sand and bond, is an eight (8) mesh screen and the second screen is a twenty (20) mesh screen. The third is a thirty-five (35) mesh screen. Suction is provided by a size 30 type E American blower fan together with a five horsepower motor.

The dust and dehydrated material drawn from the reclaimer is deposited in a cyclone dust arrester and from there is dumped periodically into a railroad car and taken to the refuse heap.

Sand and refuse from the reclaimer are drawn off in four different directions, namely—the scale, flakes and lumps from the top screen; the good sand from the second and third screens, and the split grains of sand and dust not removed by suction, through the thirty-five (35) mesh or third screen.

The good sand retained on the twenty (20) mesh and thirty-five (35) mesh screens is taken directly to the foundry and core room for use in facing sands. The refuse retained on the top screen and that through the third screen is unfit for use and is loaded into a car and taken to the dump.

Following the erection of the reclaimer, further tests were made using the reclaimed sand on different types of castings. The results of these tests were so satisfactory from a sand quality and a casting quality standpoint that without fear of serious consequences, the reclaimed sand was introduced into all molding and core sand facing mixtures. Only that amount of new sand is used which is required to make up the loss of sand which cannot be reclaimed, in this way keeping the amount of sand on hand in the foundry constant.

Results Obtained

Through the use of reclaimed sand and the use of a highly refractory durable clay (Clay B) we have been able to effect

economies in regard to the amount of new sand and clay used which were far in excess of our expectations when these experiments were started. We have been able to reduce our new sand consumption from twelve hundred pounds (1200 pounds) to three hundred pounds (300 pounds) per ton of good castings. Our clay consumption has dropped from one hundred and fifty (150 pounds) to eighty pounds (80 pounds) per ton of good castings. The saving made, represented in dollars and cents, has amounted to an average of $3,500.00 per month. It may be easily seen that our original investment of $3,000.00 for the sand reclaiming unit and the small additional cost of a high grade clay was money well spent.

Our defective losses, due to sand causes, have been reduced and the appearance of the castings is just as good, if not better, than before.

Laboratory Control

Another factor to which we attribute a large share of the credit for what success we have had in this work is the sand control methods of our laboratory. The gentlemen of the foundry industry assembled here, who have had experience with the amount of trouble that can be caused by sand in the foundry, will immediately realize that exacting and accurate control work is an indispensable asset to the foundryman. In order to maintain a minimum loss of castings from sand causes, it is necessary that we know our sand.

Permeability, strength, moisture and screen tests of all sand mixtures are run daily and conditions noted. If any wide variations from the standards set up for the properties of the different mixtures are noted, steps are immediately taken to counteract the trouble before it becomes serious.

Conclusions

In conclusion, it might be said that we attribute what success we have had in reducing our new sand consumption to the following factors:

1. Our system of reclaiming, which provides in a cheap, simple manner for the removal of undesirable material from the sand.

2. The use of a highly refractory durable clay bond.

3. Exacting and correct sand control which anticipates troubles before they appear.

From the statements made in this paper we do not wish to convey the idea that our work along sand reclaiming lines is by any means complete and we feel that in spite of the excellent results obtained and the large amount of money saved in new materials, that we are still in the infancy of this work. We are finding and developing new ideas every day, experimenting with new and radical forms of equipment, compiling results and making numerous tests—all with the idea in mind of making our new sand do all the work possible in the foundry and core room before it is finally removed to the refuse heap or classified as unfit for use.

Study on the Use of a Hardening Test for Cast Iron with Medium Silicon Content[1]

By M. Dudouet,** Paris, France

Introduction

The chemical composition of a cast iron produced in the cupola can be ascertained by analysis only after an elapse of time after the castings have been poured. It is obvious that any process which will enable the principal constituents of the metal to be determined while it is still in the ladle would be of unquestionable value.

Efforts have already been made for a considerable time to solve this problem by casting hardening test pieces. Every foundry has its own particular type of test piece, the interpretation of which is frequently uncertain and always requires a fairly considerable experience.

The hardening capacity of certain metals, moreover, is so small that with the types of test piece generally employed the reading of the hardness becomes impossible. This has led to the

[1] Presented on behalf of the Association de Technique de Fonderie de France.
**Foundry Manager, Société Métallurgique de Normandie.

endeavor to find a type of test piece sufficiently sensitive to show a visible and measurable chill or hardness in the case of cast iron of very weak hardening capacity.

Previous Research Work

Among the research work done in this direction that of M. H. Forichon (1925) must be mentioned. In his paper on the question of devising a hardening test piece for high silicon iron, M. Forichon recommends that shown in Fig. 1. He emphasizes the sensitiveness of this form, both as regards variations in chemical composition and certain other factors: casting temperature, fins, etc., and he gives some striking figures in support of his

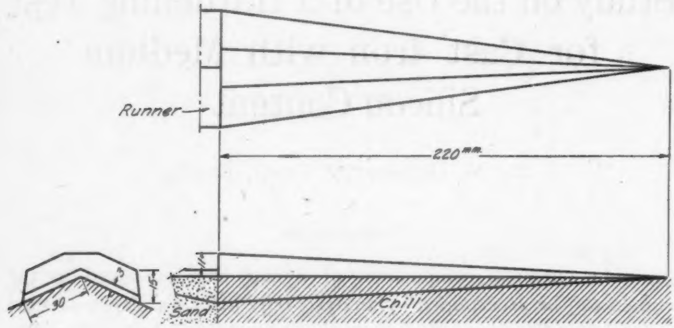

FIG. 1—HARDENING TEST PIECE FOR CAST IRON WITH HIGH SILICON CONTENT. TEST PIECE RECOMMENDED BY M. H. FORICHON, 1925

views, while at the same time stating that further experiments are required to establish them with certainty.

Purpose of Paper

In the present paper I propose to continue the study of this subject in order to determine the circumstances in which this test piece can be used in practice.

The object is to enable one to determine by merely examining a test piece the percentage of one or more constituents in the metal of which the test piece is composed.

Hardening Test

In order to attain this result use is made of the hardening properties of the metal.

What we call "hardening" in regard to cast iron is solidification in the metastable system (cementite and perlite), while the stable condition gives a graphite + perlite structure. This is structural hardening. In a fracture the two structures are distinguished by a characteristic difference in appearance, separated by a more or less distinct transition zone.

M. Forichon states in his paper that the primary factor governing the hardening is the law of cooling characterized by the velocity of the process.

In particular he examines the critical hardening velocity and its influence on the depth of hardening. The result of his reasoning, the details of which it is unnecessary to give here, is to show clearly, on the one hand, the influence of the elements, total carbon, silicon, manganese, chromium, titanium, etc., on the critical hardening velocity and, on the other, the influence of other factors (casting temperature, chills, mass and conductivity) on the cooling velocity.

From this it is deduced that, in ordinary cast iron in which the balance of Mn and S is determined, the elements, total C + Si, increase the critical hardening velocity, and that, moreover, the cooling velocity is dependent on the law of heat exchanges in the mold.

The fact that the sum of total C and Si is obtained and not the separate value of these elements is not, in my opinion, a disadvantage for several reasons:

(a) With regular and careful working the total C can be maintained almost constant in the cupola.

(b) With the Wirtz apparatus the total C can be analyzed very quickly while the hardening test piece is being cast and broken.

(c) For certain castings only the sum total C + Si is considered, particularly in the production of high resistance castings.

Summary of Tests

It may be desirable to state at once, by way of guidance, the series of tests which will have to be carried out:

(1) Determination:
  (a) of the characteristics of the Forichon test piece as applied to the cast iron on hand for the purpose of securing adequate hardening;
  (b) of the conditions under which sound test pieces can be obtained.

(2) Comparability tests.

(3) Influence of the characteristics of the test piece:
  (a) width,
  (b) thickness.

(4) Influence of the characteristics of the chill:
  (a) mass,
  (b) conductivity,
  (c) temperature.

(5) Influence of the characteristics of the sand:
  (a) mass,
  (b) humidity.

(6) Influence of the surface of contact between test piece and chill.

(7) Speed at which the mold is filled.

(8) Position of the mold.

(9) Influence of the casting temperature.

Apparatus

The chills were constructed of hematite iron of the same composition and were four in number. They were machined all over so as to be absolutely alike and interchangeable (Fig. 2).

The flasks were of aluminum and the lower flange was machined so as to be adaptable to any chill without appreciable play.

The test pieces were also obtained in aluminum, machined all over in order to be perfectly symmetrical.

Everything was constructed with sufficient accuracy to per-

mit of a mold being prepared on one chill and remolded on another without producing any *fin* in casting.

In observing the variations of temperature, although I had a partial radiation pyrometer (Cambridge) available, I preferred to employ the fluidity test piece, as being easier to use and more suitable for a foundry workshop. The whole was carried out in

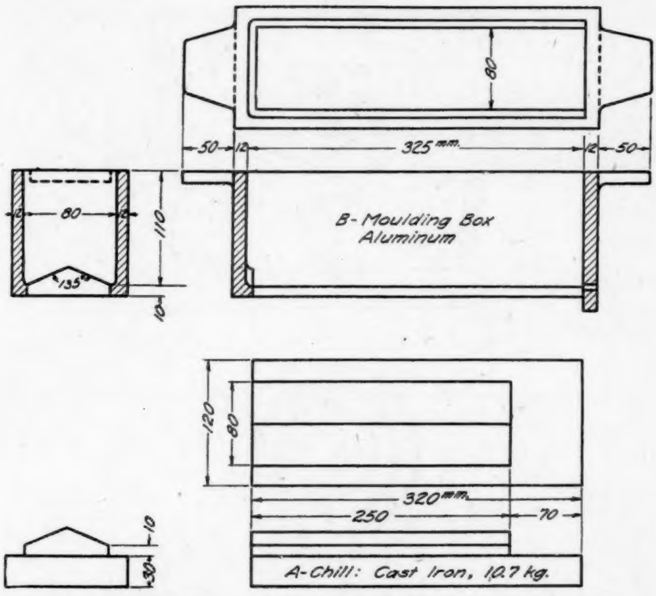

FIG. 2—EQUIPMENT FOR MOLDING HARDENING TEST PIECES

aluminum without machining, with the view of making a loam molding—this form from economic considerations (Fig. 3).

In all the tests in which the casting temperature had to be constant I proceeded as follows: the four test pieces were cast with a small hand ladle suitably heated. As the operation required about 15 seconds I took care that the fall in temperature between the first and the fourth test piece was not sufficient to falsify the readings. For this purpose I cast two Cury test pieces at intervals of 15 seconds. The test was repeated 7 times under

proper conditions and the results obtained were as follows (difference of length in per cent of that of the first test piece of each test—in progressive order):

3, 4, 4, *4*, 5, 5, 6.

The center figure gives us the mean, viz., 4 per cent which is negligible.

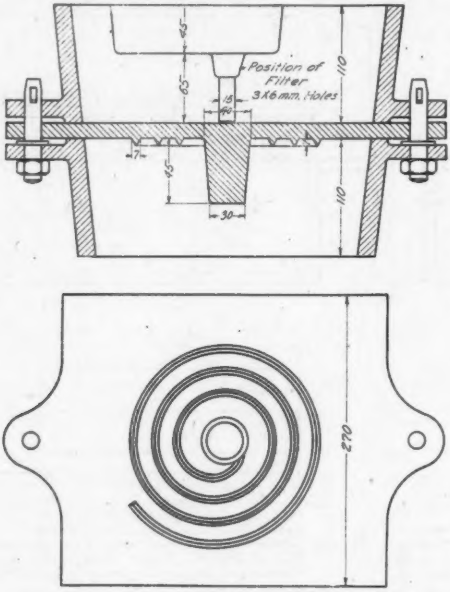

FIG. 3—EQUIPMENT FOR MOLDING THE CURY FLUIDITY TEST PIECE

As the test scheme shows, the results of each test will only hold good in so far as one factor has varied while the others remain unchanged.

This involves a rigorous verification of the conditions of each test and of the results obtained. This is undoubtedly the most important and the most difficult part of this whole study to carry out.

How these conditions were fulfilled will be shown in the section dealing with "comparability tests."

Characteristics of the Test Piece and Conditions for Casting It Successfully

I had available ingot cast iron of the following composition: total carbon 3.3 to 3.8 per cent, silicon 1.4 to 2 per cent. As the melting plant was badly designed, only an imperfectly fluid metal, not exceeding 9 on the Cury test piece, was obtained.

After several tests I decided upon the test piece shown in Fig. 4, the finished mold being shown in Fig. 5.

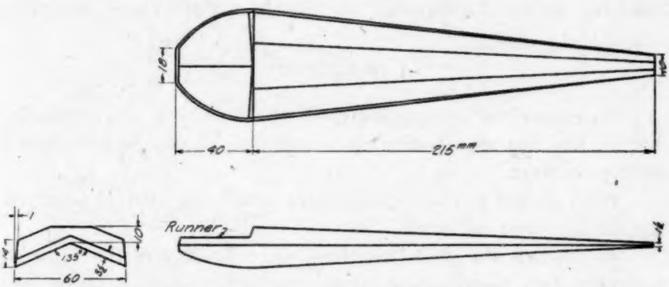

FIG. 4—HARDENING TEST PIECE FOR CAST IRON WITH MEDIUM AND HIGH SILICON CONTENT

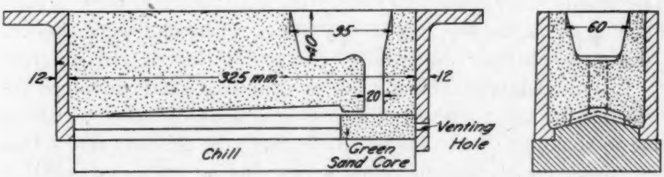

FIG. 5—MOLDING THE HARDENING TEST PIECE

There is only a slight difference between this and Forichon's test piece. The point, however, has been eliminated, as the metal used did not permit of the production of test pieces uniformly filled.

To facilitate the molding all the lateral walls have been well cleaned out.

The points to be watched in green sand molding are as follows:

Venting, particularly in the core below the runner.
Accurate setting of the cores before casting.
Drying the top of the chills with a jet of compressed air.
Rapid pouring.

The sand usually employed was new, fairly fine and of uniform humidity, viz. 8 per cent.

The molds were always made by the same workman, which furnishes sufficient guarantee as regards uniformity of ramming.

Comparability

To ensure the comparability of the results it was necessary that all the factors affecting the hardening should be maintained strictly constant.

With regard to the casting temperature, the method observed has already been indicated.

As regards the chills, as these were practically the same to ascertain their temperature it was enough to plunge them into running water a sufficient interval before casting and to air-dry them afterwards.

The sand was prepared at one operation and well mixed. The molds were placed perfectly horizontally and were always filled in the same way. The test pieces when cast were checked as regards all their dimensions, runners, included, and weighed.

As the slightest defect (*fins* or grains of sand) involved the rejection of the corresponding test series, as did also variations due to shaking, I was obliged to eliminate the first six test series.

Subsequently, seven other series having been regarded as satisfactory, I noted the following variations (in millimeters over 140 millimeters of average hardening—in progressive order):

0, 0, *1*, *2*, 2, 3, 3.

This confirms the tests made by M. Forichon, but it must be added that before molding and during casting *all precautions* must be observed to eliminate the influence of parasitic factors.

If these precautions are taken it is unquestionable that two

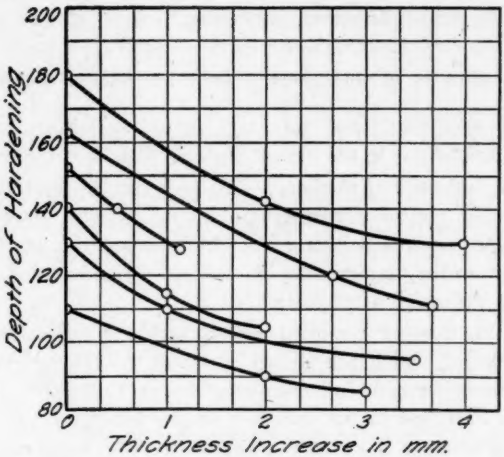

CHART 1—INFLUENCE OF THE THICKNESS OF THE TEST PIECE

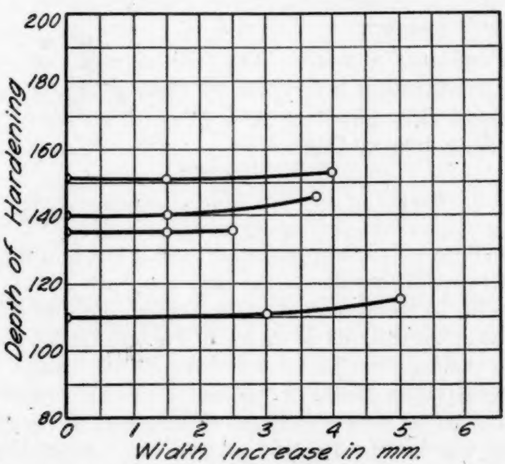

CHART 2—INFLUENCE OF THE WIDTH OF THE TEST PIECE

test pieces cast from the same metal at the same temperature show *practically* similar depths of hardening.

Influence of the Characteristics of the Test Piece

It is well that these influences should be known, chiefly so that variations due to too violent shaking may be corrected.

(a) *Influence of thickness.*—To ascertain this each test series was carried out by constructing two molds with standard test pieces, and two molds with a test piece whose thickness had been increased on the tapping side by shaking. The increase in thickness was measured after casting.

In this manner I carried out six series of *satisfactory* tests, the results of which are shown in Chart 1. The curve clearly shows the appreciable influence exercised on the depth of hardening by a variation in the thickness of the test piece. In practice a good workman, if not previously cautioned, causes an increase in thickness of as much as one millimeter by shaking. This was tested with three different workmen. In this respect it is advisable, therefore, to take every precaution by examining the test piece after it is broken.

(b) *Influence of width.*—The tests were carried out under the same conditions as before, but by shaking the test piece only in regard to width. The four series of satisfactory tests recorded enabled me to draw up Chart 2.

Influence of the Temperature of the Chill

(a) *Mass.*—For the purpose of making tests on this point I modified two chills similar to the type previously used: the first by removing 20 millimeters of material from the sole, the second by hollowing out the chill as shown in Fig. 6a. In each series of tests two standard test pieces were cast and two others with the chills altered as described. According to the three series of tests carried out under these conditions no variation in the depths of hardening was found. This is due to the fact that after the modifications mentioned there was still sufficient thickness left to produce the normal hardness in the test pieces.

Prosecuting these investigations still further, I made a chill scooped out as shown in Fig. 6b (cast from metal the analysis of which was the same as that of the previous chills).

Having carried out these tests under the same conditions as before, I found that the test pieces cast from the chill 6b showed a greater depth of hardening in comparison with the standard type.

This result appears to be absolutely contradictory of the facts generally observed in making hardened castings, namely that "the hardening is less in proportion as the thickness of the chill is reduced."

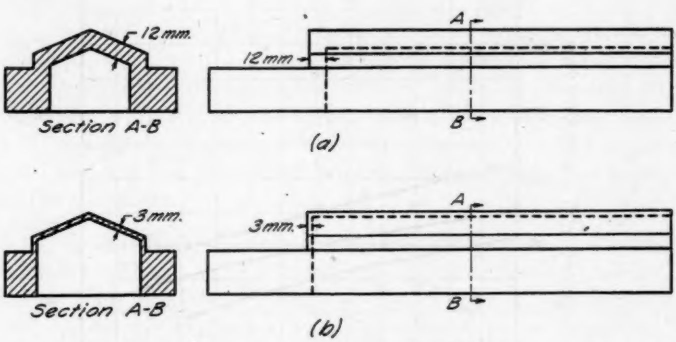

FIG. 6—MODIFIED CHILL TO DETERMINE INFLUENCE OF THICKNESS OF CHILL ON HARDNESS

In reality this contradiction is only apparent, and the explanation is given at the end of this paper.

(b) *Conductivity.*—In making tests on this point I made a chill identical with the previous ones in form but with a high copper content (Cu 98 per cent, Zn 0.5 per cent, Sn 1.5 per cent).

Comparative tests were made in the same way as before, i. e. by casting two standard test pieces and one with a copper chill. Three consecutive tests showed that the hardening was considerably increased, from 40 to 60 per cent, with the copper chill.

It would therefore appear desirable to use this special method when dealing with metal in which the total C + Si content is

very high. This would enable the same form of test piece to be used for very different metals, merely by having two chills available, one of cast iron and the other copper.

(c) *Temperature.*—It is desirable to determine the temperature of the chill so as to know to what extent it may be used after several successive castings without artificial cooling.

As measuring apparatus was not available, however, I was unable to make accurate tests on the subject.

In the comparative tests carried out for the purpose I cast

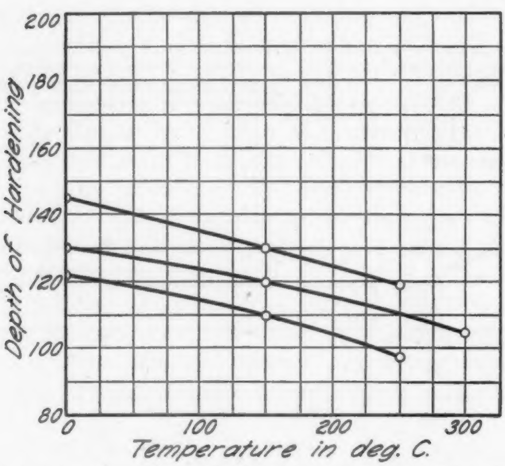

CHART 3—INFLUENCE OF THE TEMPERATURE OF THE CHILL

simultaneously two standard test pieces and two with chills which had been kept near a stove fire at different distances and for a fairly long time. The temperature of the chill nearest the fire might be estimated, at the moment of casting, at between 250 and 300 degrees Cent., and that of the other at about 150 degrees Cent. I repeated the test several times, adhering as closely as possible to the same conditions. Chart 3 gives an idea of the results obtained.

It may be concluded that below 50 degrees Cent. the tem-

perature of the chill has no *practical* influence on the depth of hardening.

It is necessary, however, to avoid attempting to estimate the temperature by placing one's hand on the chill, for it may appear to be about 50 degrees Cent. while the interior is at a higher temperature. Neglect of this detail gave me a good deal of trouble at the beginning of my investigations.

Influence of the Sand

(a) *Mass.*—The tests were made with different quantities of the same sand of uniform humidity and were carried out as follows:

Two test pieces were cast under the usual normal conditions and two others with a greater or less percentage of sand. All the other factors remaining the same, I carried out a series of tests with a 27 per cent less volume of sand, and two series with a 50 and 100 per cent greater volume respectively. In no case did I find that this factor exercised any influence on the hardening of the test pieces.

(b) *Humidity.*—Within the limits compatible with convenience in molding, I varied the humidity by about 5 to 11 per cent. Below 5 per cent the mold had no longer sufficient consistency, and beyond 11 per cent it was impossible to obtain sound test pieces.

In the series of tests four test pieces were always cast simultaneously: two with sand of standard condition and the two others with a sand of different humidity. A sample was taken from each mold, which after being dried and weighed for difference, gave the exact humidity of the sand employed.

The five series of tests carried out by this method gave the results shown on Chart 4. It appears, therefore, that the humidity of the sand has a fairly appreciable influence on the hardening of the test pieces.

The idea then occurred to me, for the purpose of eliminating this influence, to substitute for the green sand and mold a core of dry agglomerated sand as in Fig. 7.

I immediately encountered a difficulty which is prohibitive in

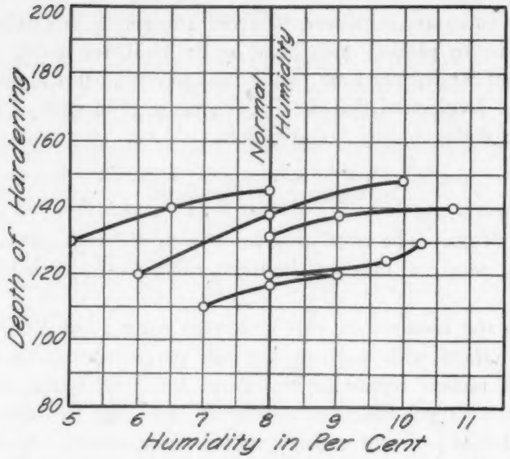

CHART 4—INFLUENCE OF THE HUMIDITY OF THE SAND

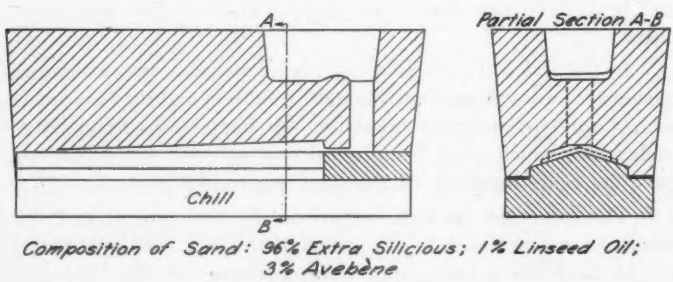

FIG. 7—MOLDING A HARDENING TEST PIECE WITH DRY CORES

practice: that of obviating fins. By taking inuumerable precautions, however, I succeeded in obtaining a few good test pieces, from which it may be concluded that with this dry sand the depths of hardening are much less than with green sand.

With the same idea in view I tried to use another green sand with the same humidity percentage. I found fairly appreciable and consistent variations. A fine-grained sand gave depths of hardening decreasing progressively. A very coarse grained sand, on the other hand, gave progressively increasing depths of hardening.

It would appear that there exists a relation between the size of the grains and the calorific capacity of the sand or perhaps the condition of the surfaces of the mold. I had neither the time nor the necessary facilities for measurement to go thoroughly into this part of the problem. The variations found, however, never exceeded 8 per cent.

Influence of the Surface of Contact Between Test Piece and Chill

In the section dealing with the influence of the width of the test pieces it may appear that the influence of the surface of contact itself was examined simultaneously.

This was not the case, for that surface may be greatly increased without appreciably modifying the form and the dimensions of the test piece, this being due merely to the presence of fins between the chill and the sand.

These fins appear to play the part of coolers in regard to the test piece and consequently, by accelerating the cooling, to increase the depths of hardening.

From the results of my observations it may be concluded that a fin which which is very narrow (0.3 to 0.4 of a millimeter) and of considerable extent (several centimeters) has much less influence than a fin which is thicker (1 millimeter) and of less extent (2 to 3 millimeters). The fins, moreover, are the less dangerous in proportion as they occur towards the massive parts. A fin near the point has no effect on the hardening when its dimensions do not exceed five centimeters.

Influence of the Pouring Speed

In obtaining sound test pieces the filling speed is limited in the diminishing sense by the casting temperature, this lower speed limit varying in inverse proportion to the casting temperature.

In all the tests hitherto carried out the pouring speed was controlled by the section of the sprue hole and gate being always kept constant, and by the feed box being placed so as to ensure a fall practically uniform in height.

Tests were made by varying only the pouring section.

From all the test pieces examined, although it was impossible to record the results exactly, it may be deduced that the depths of hardening vary proportionately to the pouring speed.

This appears logical and the explanation I suggest will be given later on.

Influence of the Position of the Mold

I have endeavored to determine the influence of the inclination of the mold in the two longitudinal directions (the point upwards and downwards) and in the transverse direction.

In each case two series of tests were carried out, two test pieces normally placed being retained, which were always cast simultaneously.

It was found that a longitudinal inclination of 20 per cent with the point upwards produced very irregular hardening and frequent defects in the test piece. The same inclination in the opposite direction showed *practically* no appreciable variations in the depth of hardening.

In regard to transverse inclination (limited to 15 per cent) a very marked effect was noted, not in the depth of hardening but on the actual hardening of the test piece.

In no case did I succeed in breaking a test piece satisfactorily; on reassembling the fragments to examine the fractures at different points I found very appreciable irregularities in hardening, the lower wing being always the least hardened.

Influence of the Casting Temperature

In these tests a hardening test piece and a fluidity test piece were cast simultaneously from metal taken from the same 1500

kilogram (3307 pounds) ladle, this being repeated four times at intervals of five to six minutes for each series.

The results obtained by following this method are shown on Chart 5.

By this chart it can be seen that the influence of fluidity (i. e., of the temperature for metals of the same composition) is the

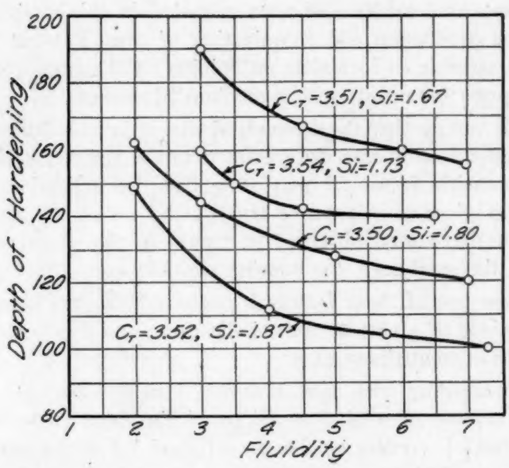

CHART 5—INFLUENCE OF THE CASTING TEMPERATURE

more appreciable in proportion as the temperature of the metal cast is diminished.

Conclusions Regarding the Use of the Test Piece Examined

Certain analyses of metals which had been used in making tests on the influence of the casting temperature have enabled me to complete the particulars shown in Chart 5.

For any one value of fluidity we can thus ascertain the influence of the sum of total C + Si on the hardening.

It may be observed that differences of 0.2 per cent in total C + Si are expressed by variations of 25 to 30 millimeters in the hardening.

I endeavored to employ the test piece in question with metals with a total C + Si content below or equal to five. Although I had then a satisfactory hardening with hot metal, it was impossible for me to estimate the depth of hardening, as the transition zone became very faint.

This uncertainty, moreover, increases as the sum of total C + Si is reduced.

As the total number of tests recorded in this study necessitated the production and examination of over 300 test pieces, I think it possible to formulate an opinion on the employment of this test piece for metals with a medium Si content.

While noting that the amount of the variations due to total carbon and silicon is scarcely greater than the variations attributable to parasitic factors, I may state that the indications given by the test piece cannot prove trustworthy unless all necessary precautions have been observed in regard to the preparation of the mold, the sand used, the pouring position, etc.

If even one of these factors is neglected, the test piece is no longer capable of giving accurate indications, and this is the chief defect I have to attribute to it.

By proceeding with care, however, I myself am able to determine the sum of total C + Si to within about 0.05—that is, with the total C content = 3.6, an error of 1 1/36 calculated on the silicon content.

In order to simplify molding, to be more certain regarding the casting temperature and to work always under identical conditions, I recommend the use of the device shown in Fig. 8, which enables a hardening test piece and a fluidity test piece to be cast simultaneously.

Remarks on the Hardening Process in the Forichon Test Piece

I endeavored to ascertain how the hardening process takes place in the test piece under consideration. At the beginning of the tests I thought that the differences in hardening, everything else being equal, was dependent on the thickness of the test piece, as the thickness governed the cooling velocity. Basing on this idea, I considered that I ought to be able to obtain similar results

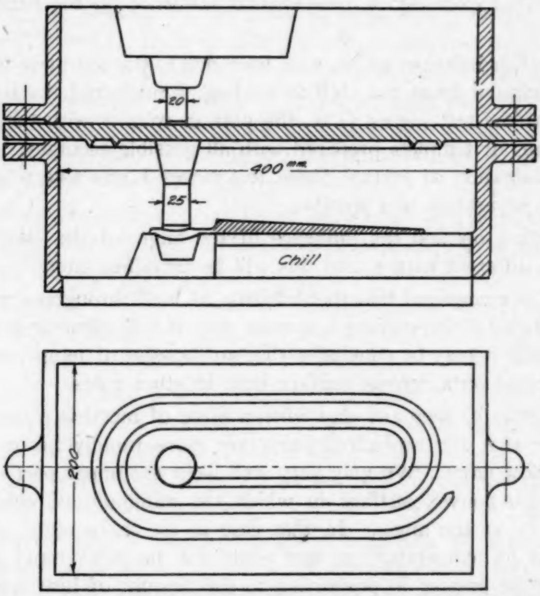

FIG. 8—DEVICE RECOMMENDED FOR MOLDING A COMBINED HARDENING TEST PIECE AND FLUIDITY TEST PIECE

by casting a test piece in the form of an elongated wedge in a flat chill.

I then found that the hardening had taken effect to a depth of two to three millimeters over the entire length of the chill.

How was it, then, that in the Forichon test piece I obtained one part white and another gray all along the surface in contact with the chill? It was apparent that the angle at the upper part of the chill exercised a fundamental influence on the hardening value.

As this influence might have been due to the test piece becoming separated from the chill in cooling, I measured the internal angle of the test pieces (i. e., the part in contact with the chill) by means of templets prepared with all possible accuracy. From an examination of several dozen test pieces I was able to decide that no separation was possible.

In my opinion the influence of the angle of the chill is of quite a different nature, and this will be explained later.

It is recognized that the diffusion of heat throughout a mass is less rapid if the surface is convex than if it is plane or concave. From this it may be concluded that an increase of temperature is more rapid on a convex surface than in other cases.

It may be seen any day when a piece of metal is placed in a furnace that the projecting parts are more rapidly heated than the hollow parts. We may very well liken the upper part of our chill to a convex surface in which the minimum of convexity would be at the angle. In that case at the moment of casting the rise of temperature at this angle will be more rapid and it will be the greater in proportion to the amount of heat supplied. But this amount of heat is proportionate to the thickness of the test piece at the apex of the angle under consideration. From the point of the test piece to the heel, therefore, the cooling velocity is influenced in the same direction by the thickness of the test piece and the rise of temperature at the angle, which is proportionate to the thickness accentuated by the convex part of the chill.

This explains why the result shown by the test piece cast with the chill of Fig. 6b is normal. In this case, in fact, I had prepared a plane hardening surface. The mass of the chill towards

the angle being insufficient to heat the latter adequately, the effect of the convexity is nil, and we have the same result as in the case of a wedge-shaped test piece cast on a plane surface. In short, the surface concerned of the chill, Fig. 6b, corresponds to a flat and fairly thin chill which has been bent longitudinally through an angle of 135 degrees.

The heating of the chill, moreover, is affected during the pouring by the wash of the metal filling the impression. It can be seen, however, that the heating will be the more appreciable in inverse ratio to the filling speed, and this is in agreement with the tests made on this subject. The irregularities noted when casting test pieces inclined on their side are explained by the irregularity of the reheating of the chill during pouring, one of the wings being filled before the other.

Notwithstanding these various agreements I wished to assure myself by other means of the influence of the angle at the upper part of the chill.

For this purpose I modified two chills which I had previously used: one by reducing the angle from 135 degrees to 123 degrees, and the other by increasing it to 147 degrees.

With the first chill I noted a very distinct reduction in the depth of hardening as compared with the normal type; with the second, on the other hand, there was an increase; yet in both cases the variation of the mass of the chill due to the modification was practically identical.

Here, then, is a further means of adapting the conditions to the composition of the metal under examination without having to alter materially the characteristics of the standard test piece, the dimensions of which make it easy to mold and break.

I was desirous of elucidating this point relating to the influence of the projecting angle of the chill on the depth of hardening, as in my opinion M. Forichon regarded the use of this angle merely as an easy means of breaking the test piece.

In closing this modest study I must apologize for certain parts of it in regard to which I was unable to carry out more accurate and consequently more conclusive tests.

The principal cause of this was lack of time. I endeavored, however, to lay down and follow a scheme of experimental work devised as methodically as lay in my power. In this I derived great assistance from the principles enunciated by M. Le Chatelier in his book "Science et Industrie."

I should like also to thank the Société Métallurgique de Normandie for giving me the use of its foundry and placing the apparatus required for these tests at my service.

Reports of Apprentice Training in Philadelphia and the Detroit District

Philadelphia Co-Operative Apprenticeship

By Charles F. Bauder,* Philadelphia, Pa.

Within the Philadelphia area, comprising adjacent territory in New Jersey, there are about 135 foundries, if we include as separate foundry departments those casting the different metals—steel, iron and non-ferrous. Of this number 77 are gray iron, 8 are steel, and 49 are brass foundries.

From a survey just made by The Metal Manufacturers' Association of Philadelphia we can estimate the extent to which the industry is developing its skilled labor supply. To this survey fifty foundries responded, reporting an aggregate employment of molders, apprentices and trainees totaling 1,273.

No statement of the training program in the foundry is adequate without a consideration of the changes in method and the further use of mechanical devices that affect the requirements for skilled mechanics. The pouring gang is more in evidence than a decade ago, increasing the potential capacity of floor molders, particularly by longer hours devoted to molding. The use of the molding machine has and is increasing. The relatively

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small order which heretofore would have been made on a jobbing side is now either gated or mounted on plate, thereby reducing the molding time required. Processing in other industries has effected the demand for castings. Smaller parts are being formed out of sheet metal by the stamping process and larger parts in a growing number of instances are being welded from heavy steel plate.

Now what is the training situation in the foundry in this important area? From the survey previously mentioned we find a ratio of one apprentice to 13 molders—52 apprentices as against 663 floor and bench molders having been reported. On the basis of a four-year apprenticeship the length of service in the trade would have to average 52 years to maintain the existing complement of skilled men without any provision for enlargement of the industry. It is unlikely if length of service will average 35 years, so that apparently the apprentice program of the district fails by about 30 per cent of being adequate to meet the future needs.

However, we find that the foundries reporting have a ratio of one trainee to eight molders, a trainee being some employe ordinarily older than an apprentice, not indentured, either unskilled or semi-skilled, working more or less under instructions and being up-graded for special work. No doubt this method of supplying the requirements of skill is as effective or more acceptable than apprenticeship, as there are approximately 60 per cent more trainees than apprentices. We find by combining the number of apprentices and trainees that our ratio becomes 1 to 5, the traditional figure promulgated by the labor unions many years since and one no doubt adequate to maintain the complement of skilled men.

Machine molding is not regarded as warranting apprentice training and in many instances work on the machine is but an introduction to work on the bench or floor, requiring more skill and dexterity. The ratio in machine molding is 2 employes under instructions to 7 mechanics.

In coremaking the ratio of those in training to mechanics is 1 to 5. Coremaking likewise is not regarded as requiring as much skill as molding, the smaller work notably being done either by girls, boys or semi-skilled help.

In toto we find a ratio of apprentices and trainees to mechanics of 2 to 9. Apparently, therefore, our training program is not as inadequate as it has been assumed, at least not in quantity. But what about its quality?

It is indeed a rare occasion, so I am advised, when we have a plethora of really skilled foundry mechanics, but a common occasion when the foundry is seeking qualified help without success. Quite recently foundry production has been much below normal and yet I am informed that distinct difficulty has been experienced in obtaining help qualified to meet the foundrymen's requirements.

With all this in mind, for this situation has been with us for some years, The Metal Manufacturers' Association of Philadelphia, with the cooperation of the Philadelphia Public Schools, formulated in 1926 its Co-operative Apprenticeship Plan for the training of skilled men as machinists, pattern makers and molders. A committee of that association worked with representatives of the schools in laying out a schedule of supplemental academic and technical instruction relating to these trades. These classroom subjects are taught in the schools for four hours on Saturday mornings, the classroom work running for the full length of apprenticeship—four years. All the teachers of the specific subjects are either men who have had industrial training or have had years of contact with industry through teaching industrial subjects in the evening schools. The teachers of the trade science particularly are all practical industrial men.

The plan calls for a schedule of operations performed in the shop in order that the apprentice may get the rounded out experience essential to qualify him as a mechanic. Apprentices are paid shop rates while attending schools and regular reports are rendered to management, records of progress in classroom work being as much a factor in determining their standing as an apprentice as those on shop work.

Beginning in the fall of 1926, fourteen plants participated. We now have twenty-three plants cooperating in this program, nine of which have apprentices enrolled in molding. It is confidently expected that additional plants will adopt this cooperative apprenticeship plan and that the enrollment of 100 apprentices

now will be materially increased with the opening of the fall session.

I have purposely not burdened you with further details of this plan, all of which are contained in a booklet published by The Metal Manufacturers' Association of Philadelphia and which can be obtained on application to them. I am, however, prepared to answer questions as to this detail if the meeting desires.

Apprenticeship in the Detroit District

By W. J. Hebard,* Detroit, Mich.

Industry in and about Detroit has been developing so rapidly in the past few years that little time has been devoted to the problem of apprentice training. Mechanics from various parts of the world have been moving in, drawn by the lure of high wages, and it seemed for a time that the needs of industry were fairly well provided for. Lately, there has been a growing realization that the policy of relying upon the training activities of plants in other cities is not as satisfactory as it might be. Hence, the increased interest and activity in apprenticeship.

Of course, there has been some training done in various plants in this district for many years, but it has only been a small fraction of what was necessary. There are a number of small shops where apprenticeship is a tradition and in such places one or two boys are always in training. Usually there is no very definite program to work to and the superintendent or one of the foremen simply keeps an occasional eye on the apprentice.

Perhaps the greatest factor in bringing the need for apprenticeship to the attention of industry in this district has been the activity of such associations as the A. F. A. The stress laid on training programs at the various meetings has caused a beginning of activity even in this locality where the expression "production methods have made training unnecessary" had really been believed.

The following brief summary will indicate what is actually being done in this district. The apprentice committee of the De-

*Apprentice Consultant, International Correspondence Schools.

troit Foundrymen's Association has started to get foundry training under way and we hope to hear more from them a year from now.

Detroit

The vocational department of the Detroit Public Schools has been actively interested in apprenticeship for some years past. At the present time, most of the plants' training apprentices are co-operating with this department. Classes in trade mathematics and in mechanical drawing have been organized and the apprentices are sent to school for one-half day each week. Each plant has its own program of shop work and there has been no attempt made at organizing in a community way.

A summary of the metal trades apprentices in these classes is as follows:

Machinist	6
Tool and Die	50
Pattern	10

These apprentices are employed by such firms as Morgan and Wright (Division of U. S. Rubber), Dodge Brothers, American Blower, Hupmobile, Detroit Steel Products, Chrysler, Packard, Monarch Governor, Paige Motors. In addition, there are two alloy foundry apprentices at the Bohn Aluminum and Brass Company. So far as is possible to learn, there are no iron or steel foundry apprentices in Detroit.

The Studebaker Corporation employs approximately 40 tool and die apprentices, all of whom are working on a three year course. The class room work is handled within the plant and recently I. C. S. trade apprentice courses have been prescribed to supply material.

The Burroughs Adding Machine Company has carried on a training program for many years. At present there are 20 machinist apprentices, 10 draftsmen, 3 printing, and 2 pattern. Until recently these apprentices attended the Detroit Apprentice School. Now, however, the company has set up its own classes within the plant with instruction in shop mathematics and mechanical drawing.

In addition to the programs mentioned, there are several small plants, having a few pattern, machinist, or tool-making apprentices. The Ford Trade School is considered separately.

The building trades have been more active in apprentice training in Detroit. Co-operating with the contractors and the various trade unions, the Detroit schools are now providing class room instruction for 668 apprentices as follow:

Bricklayers	175
Plasterers	90
Electricians	240
Tile Setters	20
Metal Lathers	20
Plumbers	40
Steamfitters	35
Painters and Decorators	48

Also, there are 80 printing apprentices employed in various printshops in the city.

Henry Ford Trade School

Henry Ford feels that even young boys should produce things of value as part of their education. To demonstrate this belief and to help underprivileged boys, he founded the Henry Ford Trade School in October, 1916. From a beginning with six boys and one instructor, it has grown in ten years to an enrollment of 1,800 boys and 125 instructors. True to the purpose of its origin, needy boys are given the preference.

The school is incorporated under a Michigan statute to operate without profit. Boys between the ages of twelve and eighteen are admitted. The academic requirement is that the candidate shall be in the school grade for boys of his own age. The school work is divided into two departments. For one week the boy attends academic work only and during the following two weeks he works in the school shop.

Upon entering, a cash scholarship amounting to $7.20 per week is awarded to each boy. This is paid him on the fifth and twentieth of each month throughout the entire year, including a vacation of three weeks in the summer and one week at Christmas.

Each six weeks a report is made covering the shop and class work. As long as the reports are good the boy receives an automatic increase amounting to 40 cents or more per week. A boy who applies himself should receive $12.80 and $16.00 per week at the end of his second and third years. By the time the boy is 17 years old, he should have a scholarship rate of $18.00 per week,

which is the maximum for a boy until he is eighteen, when he completes the junior course.

During the academic week the boy attends class work only. The entire course includes:

English	Trigonometry
Mechanical Drawing	Physics
Civics	Chemistry
Auto Mechanics	Qualitative Analysis
Commercial Geography	Quantitative Analysis
Arithmetic	Metallurgy
Algebra	Metallography
Geometry	Shop Theory

Boys who wish to attend college take history and foreign language in some other school. Many of the boys are doing this.

In order to give them a better appreciation of actual shop conditions, boys who have had sufficient training are placed in departments of the Ford Motor Company when they reach the age of sixteen. They continue their class work every third week and are at all times under the jurisdiction of the school.

Boys under sixteen receive their mechanical training in the school shop which is separate from the Ford Motor Company and covers three acres of floor space. On one floor is a series of rooms totaling a length of 1,400 feet with an average width of 70 feet. In this shop are hundreds of the finest machines of many types. The total equipment is valued at over a million dollars. In this shop there are 18 departments, and two men spend their entire time moving boys from one department to another as fast as they have completed the requirement.

In all this training the school holds the following ideals before the boys, in the shop and, as far as possible, in the class room: cleanliness and safety come first, then accuracy. Slow accuracy is no longer valuable, therefore speed is the fourth ideal. Fifth is originality, the ability to develop better methods and better work.

At eighteen the boy enters the senior course. He works in the shop eight hours each day and attends class work in advanced drawing and mathematics four hours each week. His rate is gradually increased to $30.00 per week by the time he is nineteen, and may reach $40.00 per week when he is twenty. At

twenty or before he is offered a position in some department of the Ford Motor Company.

The Board of Education for the State and City approve the work of the school.

Graduates of the school are today holding important positions in the Ford Motor Company and elsewhere, and the results seem to justify Mr. Ford's faith.

Pontiac

Oakland Motor Car Company

At the end of the first year of this program, there are 25 regularly indentured apprentices in the following trades: toolmaking, machinist, diemaking, electrical maintenance, general maintenance, auto service, design, heat-treating, and machine repair. Foundry apprentices will be included in this program when the new foundry is completed. Plans call for a maximum of between 75 and 100 apprentices when all departments are included.

The courses vary in length from two to four years, depending upon the previous education and experience of the applicant. Definite schedules of shop operations are closely tied in with related courses of study by means of correspondence courses supplied by the I. C. S. The apprentices spend four hours each week in class at the local high school under the direction of a capable instructor. The subject matter includes shop arithmetic, applied drawing, shop methods, together with shop talks on such subjects as company organization and policies, safety, personal hygiene, etc.

Wilson Foundry and Machine Co.

This plant produces the Willys-Knight and Whippet motors. For some time there have been apprentices in the tool room, at the present about fifteen being in training. These boys are on the usual three year apprenticeship, following a definite shop schedule. Recently arrangements were made to have the local high school furnish instruction in shop mathematics in special evening classes.

In the very near future it is planned to start a foundry apprentice course. A maximum of about 20 foundry apprentices can be taken care of properly.

The vocational director of the Pontiac High School intends to build up a community interest in apprentice training, using these two plants as a nucleus to begin with.

Bay City

The community apprenticeship program for Bay City, sponsored by the Bay City Chamber of Commerce, was reported on at the 1927 convention in Chicago by W. B. Perry, works manager of the Industrial Works.

This program was started in the Fall of 1926, shortly after the 1926 convention in Detroit, and was inspired by the discussion at the session on apprenticeship of that convention. The Chamber of Commerce invited H. A. Frommelt, chairman of the apprentice committee of the American Foundrymen's Association, to meet with their apprentice committee for the purpose of outlining a method of procedure. As a result, a survey was made of the local industries to determine the approximate needs of the community. After considerable discussion and delay, a working plan was laid out, which is briefly, as follows:

A definite plan was worked out for each of several plants, indicating the number of apprentices, the trades to be taught and the schedules of shop work for each trade. A tentative schedule of rates was set up, although it was made clear that each plant could deviate from such rates as it saw fit. Arrangements were made with the superintendent of schools for a four hour class period for all apprentices. The material for class room work was to be provided by International Correspondence School apprentice courses. Provision was also made for interchange of apprentices whenever this seemed the proper thing to do.

The preliminary investigation indicated that approximately 400 apprentices could be provided for when the maximum had been reached. This represented about fifteen different trades, including 40 foundry, 10 patternmakers, and 200 machine shop. At the present time there are apprentices actually under indenture in only five plants, a total of 50 apprentices attending the classes each week at the local high school.

The start of this program has been slow, perhaps, but it is gathering momentum steadily. It is the intention of the apprentice committee to keep going until every one of the forty plants

is actively participating in the movement. When the maximum of 400 apprentices has been reached, the future needs of Bay City will be well provided for.

Lansing

The Reo Motor Car Company organized their apprentice program in 1918 and now have a total of about 200 apprentices in toolmaking, diemaking, and sheetmetal apprenticeships. Seven full-time men are employed as instructors for both shop and class work. A separate machine shop has been set up for the training of new apprentices. This shop also acts as a reservoir for supplying the various shop departments when necessary. A recent survey disclosed that of 270 graduates, 76.6 per cent are still in the employ of the Reo Company and 50.4 per cent are holding jobs above the rank of journeyman.

At first, all of the class work was handled by the company instructors with courses of study which they had outlined. Now, however, some of the apprentices are enrolled in correspondence courses and study them in the company class room.

South Bend

The Studebaker Corporation started just three years ago to train a few toolmakers and diemakers. Now their apprentice group includes thirteen trades and almost one hundred apprentices. All courses require a three year term, beginning with a probationary period of about three months. Incoming apprentices receive their preliminary training in a separate machine shop and are then shifted to various departments in the plant. The increasing value of the program can be seen in the demand for apprentices to fill the gaps in many departments, both for temporary assignments and for permanent positions.

Included in the number of apprentices are: 65 machinist diemakers and toolmakers, 15 draftsmen (including body designers and chassis designers), 2 blacksmiths, 5 electricians, 2 pipefitters, 2 power house, 4 metal patternmakers, and 3 maintenance men. Related study in each of the trades is furnished by I. C. S. apprentice courses, which are studied in the company's own class room.

What Material Handling Equipment Can Do for the Jobbing Foundry

W. B. Marshall,* Milwaukee, Wis.

Justification for material handling equipment is cost reduction per unit of output whatever the product may be and in this respect the jobbing foundry is no different than any other industry where materials are handled in large quantities. For example, in power plant work the cost per kilowatt hour can be reduced by the use of efficient coal handling equipment and in central mixing plants where concrete is being mixed and poured, sand and gravel elevators and conveyors, if properly applied, can reduce the cost per yard of concrete. There are various ways in which material handling equipment can reduce the cost per unit of output.

1. Saving floor space, thus reducing fixed charges for buildings and property.
2. Increasing volume of output, thus dividing the fixed charges of the plant into more units of output and decreasing the unit cost.
3. Insuring established output by setting a pace for the actual work being done.
4. Reducing indirect labor charges by cutting down the handling between operations and other labor not directly applied to the manufacture of the product.
5. Reducing direct labor.
6. Reducing labor turnover by improved operating and safety conditions.

*Sales Engineer, The Chain Belt Co.

7. Improving the quality of the product and thus increasing the salability. This may mean an actual reduction in selling cost or an increase in the volume of sales.

These advantages common to material handling equipment apply to any industry and may be secured individually or as a whole in jobbing foundries.

Continuous foundries have taken advantage of practically all of these factors and in this respect have pointed the way to the possibility for cost reduction in the jobbing foundry. The jobbing foundry, however, offers a much more difficult problem because the variety of work and the often unsuitable layout of buildings in the various units of the foundry make it difficult to apply material handling equipment economically. Flexibility is a very important factor because most jobbing foundries have no definite guarantee of business over a long period of time, and since the work is constantly changing there is always the possibility of a different method of analyzing the suitability of any kind of equipment which may be required.

To get the most economical application of material handling equipment requires certain fundamental conditions. First, the units to be handled should be segregated as to size, as far as is practical, because this determines the size of the handling unit and the size must necessarily be based on the largest size. Also the flow of material should be as continuous as possible to keep down the maximum demand at any one time, because the size of the material handling unit does not depend on the average daily capacity required but on the maximum momentary demand.

Second, the location of the operating equipment such as molding machines, shakeout gratings and other parts which feed the conveyors should be in direct lines as far as is practical in order to simplify the design and number of material handling units. They may not necessarily be in a straight line, for the design of mold conveyors (for example) may be well adapted to operate in a loop, but the location of the operating equipment should be a location which will make the application of conveyors economical without special construction.

Third, the required capacity should be at least equal to the minimum practical design of standard material handling equipment in order to secure a maximum return from the investment. As an example of this, belt conveyors, due to the openings re-

quired to receive the sand, should be at least 16 inches wide. However, a 16 inch belt will handle probably 30 tons per hour if used on troughing carriers and any system involving the use of troughed belts at lower capacity would not be utilizing the equipment to its fullest extent. This may not be a deciding factor as to whether a belt will be used or not but it should be taken into careful consideration.

Fourth, the utilization of existing handling equipment such as cranes, pouring monorails, tracks in the floor, and other forms of material handling should be carefully considered in order that they may be used as far as possible. They represent an investment, and to disregard them may mean entirely unnecessary expense.

Fifth, consideration should be given to the pits and foundations required as well as changes to existing buildings, also the relocation of existing equipment. Many times it may be cheaper and more economical in the long run to modify the location of the material handling equipment than to re-build or re-locate a building or foundation in order to accommodate it.

These are all comparatively general statements, although they have certain direct reference to the jobbing foundry, but the application of material handling equipment to the jobbing foundry at present is primarily in three ways:

1. Sand conditioning equipment.
2. Sand handling equipment.
3. Mold handling equipment.

Sand conditioning, sand handling and mold handling include the bulk of material handling with the exception of the materials that go to make up the melt. Since the problem varies so widely between ferrous and non-ferrous foundries in the handling of materials for the melt, it is not my intention to go into this problem. It may be said, however, that great strides are being made in the economical handling of materials in ferrous foundries from railroad cars into storage and then from storage into the cupola. This will undoubtedly be covered in another paper during this session.

Sand conditioning and sand handling, however, is common to all jobbing foundries and the problem does not vary fundamentally in the case of either ferrous or non-ferrous foundries.

Sand conditioning is distinctly a material handling problem. The trend is towards more and better mechanical sand conditioning, because sales competition is requiring foundries to turn out better, higher quality castings and cost competition is also demanding less scrap in foundry operation. Further than this, these two demands necessitate uniform and consistent results and mechanical conditioning by eliminating most of the human element makes it possible to secure these results continuously.

Molding sand research has begun to establish standard requirements for tempered molding sand by setting up a definite measuring stick for grain size, bond, permeability and moisture content.

Mechanical conditioning equipment will insure the uniform and continuous attainment of these requirements and eliminate the human element and consequent variation from standard.

It is not my intention to discuss the relative merits of various types of sand conditioning equipment now on the market. Each one has its particular place in a jobbing foundry because of its ability to give certain of the above mentioned properties to the sand to be conditioned. Each one also has its own background of accomplishment in doing its job in some of the foundries throughout the country and any foundryman can determine from the manufacturers of the equipment or from other foundrymen just how well it has met the required conditions. It should be mentioned in passing, however, that foundry sand conditioning does not apply to molding sand alone but also to the core sand and facing sand preparation and these are also vital factors in the production of higher quality castings. It seems to be generally recognized that sand conditioning equipment will justify its cost in securing the above advantages. One warning, however, might be mentioned in this respect and that is the trend is sometimes toward over-equipping for conditioning. This undoubtedly is due to a lack of definite information as to the results obtained through the use of various conditioning units. With a standard set-up and with routine tests of the molding sand, there should be no reason why proper units for conditioning equipment could not be applied without involving a great complexity of units.

Sand handling equipment, however, is more complex in its application because each system must be tailor-made to fit the foundry in question. Consideration must be given to:

1. Foundry building layout.
2. Location of molding machines, molding floors, shakeout points and location of the sand conditioning unit.
3. Capacity required.

Hence each proposed installation must be analyzed on the basis of the economical application of suitable equipment as outlined above and this compared with the actual cost reduction which can be secured. As examples, certain actual accomplishments can be cited and general conclusions drawn.

A jobbing steel foundry, after installing for its central sand conditioning unit material handling equipment consisting of elevators, overhead sand bins and electric lift trucks for distributing sand to the molders, accomplished direct labor savings amounting to over $10,000.00, the sand handling labor having been reduced from 120 hours to 59 hours per working day. Two ten-hour shifts of six men each were formerly required. Now, five men working days only, plus three hours for three men on the night shift, is all that is necessary. In other words, this has meant a saving of $2.00 per ton of castings produced.

This same saving has been accomplished in other foundries and it is conservative to assume that at least 15 per cent per ton of sand handled can be saved by the use of material handling equipment. Other direct advantages to be obtained through the sand handling equipment may be summarized as follows:

1. The temperature of the sand is more uniform. Spreading it out over the belt feeder, discharging it into the bucket elevator, and then for a considerable distance into an overhead hopper, not only equalizes it but actually reduces its temperature.
2. The sand is also better because all rods, nails, scrap, etc., have been removed. This separation of rods and scrap from the sand has also decreased the maintenance cost of the mill.
3. A big saving is also effected from the salvaging of the rods, scrap, etc., and in this particular case during one month of operation, almost 23,000 pounds were removed from the sand.

In another instance the problem was of a different nature and increase in capacity was secured in the existing plant by the application of suitable sand handling equipment and production was increased 300 per cent. This was made possible by providing an overhead supply of sand for the molding machines, shakeout conveyors and a central sand conditioning unit.

A description of the particular application of the various suitable types of conveyors and elevators, such as belt conveyors and elevators, scraper conveyors and elevators, magnetic separators, and steel apron type conveyors would be beyond the limits of this paper. In general it should be mentioned that the handling of sand, particularly when tempered, is a most difficult conveyor problem. The proper design of chutes and bins to prevent sand from sticking and building up is very important. Also, sand being highly abrasive, the equipment should be designed with ample bearing and wearing surfaces to give sufficient life to justify its cost. Simplicity should be paramount in any sand handling system.

Mold handling equipment in jobbing foundries also requires careful analysis due to the various rates at which different jobs can be molded and the variety of sizes of molds and flasks. Also certain molds may require more careful handling than others and even slight vibration must sometimes be avoided. Where molds can be segregated into groups of reasonably uniform size there may be sufficient output in one group to justify a continuous power driven conveyor and provide for a continuous supply of iron for pouring. This has actually been done in at least one large foundry and is being planned in others.

Where this is not possible, gravity roll conveyors have been used to serve as mold storage racks and are loaded at one end next to the molding machine and poured off and shaken out at the other. In this way the handling of molds is reduced to a minimum and molds are kept in a constant straight line flow. Not only is the molder relieved of handling, but pouring and shaking out labor is used more efficiently and corresponding savings in cost can be secured. Flasks, bottom boards and pouring weights can be returned to the molder on gravity roll conveyors which also means a saving in labor cost.

In conclusion it can be pointed out that the installation of material handling equipment does not necessarily mean a large investment of money. Analysis will show how much equipment can be installed and justified by the reduction in costs it will accomplish. Actual experience has shown that jobbing foundries can reduce costs by the correct application of material handling equipment.

East Chicago Community Training Program

By H. R. Packard,* East Chicago, Ind.

During the past decade or two we have witnessed the phenomenon in this country of communities going bankrupt in a personnel sense. The economic changes which came immediately after the war disclosed the fact that skilled personnel for many, if not all, of our major and basic industries was considerably below actual requirements. The National Industrial Conference Board has estimated that approximately one million young men should be in training in our industrial plants. There can be no question that we are training less than 10 per cent of this number through formal apprenticeship at the present time. The restrictions of immigration have tied up the European sources of the skill with which, to a large extent, we formerly manned our industries.

However, it is a far cried story from the statement of the needs to the actual supplying of this skill. Significantly enough, in the past only a few of our larger industrial establishments throughout the country maintained formal industrial training programs. A close examination of the situation will immediately reveal the reasons. Only the larger establishments in a community can set up and maintain adequate training facilities. It is difficult to realize in this country that less than one-half of one per cent of all manufacturing establishments employ over 1,000 men; more than 85 per cent, according to the last government census, employ less than 100 men. It is this 85 per cent with which we must deal in any industrial community. Some plan

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must be evolved by means of which the smaller industries can participate and do their proportionate share of the training.

Chambers of commerce are generally strategically situated to direct community programs of industrial training. They all have close contact and communion with the industrial establishments of their communities. It remains only for an organized and well manned chamber to evolve an adequate program and enlist the support and participation of its constituent manufacturing membership. Moreover the educational requirements of the modern industrial training program can easily be provided through a chamber of commerce enlisting the cooperation of the local public school organization or the vocational educational department of that organization. Community representation is likewise equally feasible and possible. The three elements of the community; namely, the industries, the schools, and the civic body, generally must be represented in a program of this kind.

Chamber of Commerce Organizes Plan

Just about a year ago the East Chicago Chamber of Commerce, East Chicago, Indiana, realizing the importance of such an industrial training activity, directed its attention to the evolution of an adequate plan for its industries. A year of intense preliminary research work followed. A committee of the industrial division studied the needs and gathered reams of information and pages of data. The experiences of other communities, though limited in number, were drawn upon. It was discovered that the community plan for the training of the skilled personnel necessary to the industrial well being of the community was not only feasible but that it had been proved a success in other districts.

With the beginning of the current year, paper programs were translated into realities. At the present time 85 indentured apprentices are at work learning the essentials of their respective trades and attending school one-half day per week for the related or technical training so essential in their apprenticeship.

After much deliberation this continuation plan was decided upon as being the most practical and best suited to local conditions. Apprentices are indentured to individual plants and are schooled through the essential operations of their trade at actual shop work. This portion of the plan is continuous and is distinctly different from the cooperative plan, whereby apprentices

work and attend school generally through alternate two-week periods.

The only exception to their continuous employment in the industry to which they are apprenticed is one-half day per week, which is set aside for their classroom instruction and training. During this period, for which they are paid at the going apprentice rate, they attend the Washington High School in a class set aside for their particular needs. This is being conducted under the auspices of the vocational educational department of the local school system.

Thus the two essentials of modern trade training are adequately met. The manual or craft portion of their training is provided for by detailed schedules of shop work covering all essential operations of their trade. The educational phases of the trade work, which cannot be provided on the job, are supplied by actual classroom study. Here an order of studies suited to each trade is carefully pursued. In general these cover the following four main divisions. English; mathematics adapted to the trade; technical or related studies; and finally a general division including shop economics, safety, hygiene, etc.

Administration of Program

The administration of this program under the auspices of the chamber of commerce has been directed by an Advisory Committee, whose personnel consists of representatives from each participating plant and the local schools. The Advisory Committee has four sub-committees under its general jurisdiction. The policies and general direction of the program rest with the main committee. School methods, shop schedules, administration details, and wage scales are represented by separate subcommittees.

The Apprenticeship Administration Committee designs and deals with the administration of training programs, not only within individual plants, but also as regards the community program where such details are common to all plants.

The School Methods Committee is the link between the industries and the local school organization. For example, it provides, by means or displays, all materials and equipment of shop atmosphere and background so necessary to the conduct of the school portion of this plan.

The Shop Schedule Committee provides an organization to assure adequate shop schedules. Wherever complete programs are impossible in any one plant, owing either to a lack of diversity or quantity of production and manufacturing operations, this committee can arrange for an interchange of apprentices to the end that adequate shop schedules can be presented to every apprentice. Thus, if a smaller establishment in the community finds it impossible to provide a complete program of shop work essential to the trade in question, apprentices from this plant can be loaned or farmed out to a larger establishment in the community where the remaining portion of the shop work can be provided.

The Wage Scales Committee has general jurisdiction over apprentices' rates of pay. Obviously, it is essential to the successful conduct of a program of this kind that all establishments pay the same rate of pay in any given trade. Revisions of these schedules, whenever necessary, are entrusted to this committee.

These groups have been functioning since the first of the year and have provided excellent administration of this program. All apprentices are interviewed through the Apprentice Training Department of the Chamber of Commerce. A complete and adequate file is provided for this purpose at the chamber of commerce. As apprentices are required in the industries they are sent from the chamber of commerce and the necessary changes in its files are made. The routine machinery to arrange the school portion of the program between the industries and schools, the parents of the apprentices and the chamber of commerce, has been set up by the Apprenticeship Administration Committee. All forms have been reduced to the minimum necessary for such training, so that the flow of apprentices from the community, through the chamber of commerce to the industries and into the schools goes on smoothly and quietly.

Order of Studies

The following order of studies for a machinist apprentice is the detailed schedule for the four hours of classroom work:

1 hour—Safety, health, hygiene, economics, and English,

1 hour—Mechanical drawing and shop sketching,

1 hour—Related mathematics,

1 hour—Reading related to the occupation.

It is necessary to supplement this, however, with lectures, inspec-

tion trips, classroom display of shop materials and equipment, and enlarged or embellished courses of study.

Shop sketching, for example, to refer to the latter instance, is enlarged upon by the study of actual castings suitable for the purpose in the classroom. Thus apprentices are not only spending some portion of their time at mechanical drawing but, what is far more important, at actual shop sketching. A classroom display of all essential shop materials and equipment has been set up in the classroom where the 85 apprentices attend school in five groups distributed over five afternoons each week.

Lectures centering around special manufacturing operations or outstanding technical branches familiar to the locality supplement the actual class work as provided for by the above order of studies. A few of the two hundred hours per year which each apprentice must spend in the classroom are used for inspection trips to plants in this and neighboring communities, but here again a definite program has been arranged, to the end that inspection trips become more than merely sight-seeing tours. Reports covering these trips are required from each apprentice.

A close relationship between the school personnel concerned with this plan and the industries makes it possible for the instructors to maintain in the classroom the shop and trade background so necessary to a successful trade training program. This and other vital details have been prosecuted by the Shop and School Methods Committee.

Cooperation of Plants

Unless adequate schedules of shop work comprising the essential operation of each trade are provided in any apprentice training program, it must of necessity fail sooner or later. To insure this in the East Chicago plan, ideal schedules for each trade were prepared in turn. Each participating plant next prepared for those trades the schedule of operations best suited and possible to its own manufacturing operations. These schedules were then compared with the ideal to insure that no large discrepancies might creep into any individual plant program.

However, where it has been impossible for an individual plant, owing either to its lack of diversity or quantity of manufacturing operations, to conform quite closely to the ideal schedule, interchange of apprentices has been agreed upon. Accordingly,

the apprentice from such an organization will be able to complete his training in a larger plant in the community or at least in one which can provide such operations as are lacking in his original schedule.

The apprentice, however, is indentured to an individual plant and remains the employee of that plant throughout his apprenticeship. While at work in another plant participating in the program, he comes under the immediate jurisdiction of that plant and is paid according to the going apprentice scale by the plant for which he is personally working. The Shop Schedule Committee thus is in a position to insure adequate shop training for each and every apprentice in the community.

Rates of Pay

The apprentices are paid at a rate which insures the possibility of supporting and maintaining themselves upon entering their apprenticeship. This schedule of rates increases every six months or approximately every 1200 hours, until at the end of the four years of training the apprentice is receiving about 75 per cent of a mechanic's rate. Changes in these schedules, which differ slightly for the various trades, can be made only under the direction of the Wage Scale Committee, whenever such revisions seem necessary. All participating plants pay a uniform apprentice rate for each trade.

Plan Meets Need of Young Men

This plan of training is designed to meet the needs of young men leaving school, for whatever reason, either grade school, high school, or college. The minimum requirement which has been set is a grade school education. A boy leaving grade school and entering an apprenticeship must spend four years in trade training. A young man who has completed high school is given one year's credit and will therefore complete the same shop schedule in three years. A college graduate must devote two years to the same program. The young men in the community are encouraged to continue their formal school education as long as possible. Many high school graduates are at present serving apprenticeships and it is hoped that in the course of time these numbers can be increased. However, the program both as regards shop and

related school work has been prepared to meet the needs of these three classes.

The related school portion of this apprentice training is entirely on an individual basis. Each apprentice pursues a course of studies fitted and adapted to the trade he has entered and he proceeds at his own pace unhampered and unhurried by any other apprentice in the community. Instruction is devoted entirely to assistance and guidance for the individual. This is necessary, not only because of the varied previous educational experience of individual apprentices, but also because apprentices must necessarily be inducted at any and all times throughout the year. The apprentice is given four hours per week on the employer's time to pursue the technical essentials of his trade. He is required, however, to spend an equal amount of time in home study work. Class supervision and direction of the school program insures the fulfillment of these requirements.

All of the essential factors in this program are incorporated into an apprentice indenture or agreement to which the employer and the apprentice, with his parents or guardians, are parties. The indenture sets forth in detail the shop and school schedules, as well as the rates of pay according to which the apprentice will work throughout his term of training. The employer agrees to provide employment approximately according to this schedule and the apprentice is assured of employment regardless of business conditions, except of course in the case of complete cessation of operations. The apprentice and his parents in turn agree that he is to remain in training throughout the term specified.

The apprentice indenture, however, is not the sole link connecting the various interested parties. Each month the apprentice and his parents receive a report card setting forth in detail the shop and school grades attained during the past month. Parents are interviewed at the time the young applicant is interviewed, either at the chamber of commerce or at the plant to which the apprentice has been sent.

Growing List of Applicants

Eighty-five apprentices to date are attending the local Washington High School for the one-half day classroom portion of their training. Approximately 125 are working as apprentices in the eight manufacturing establishments participating in this

program at present. The discrepancy between these figures results from the fact that some apprentices who were previously employed at the plants in question had progressed to the point in their term of training where it was thought inadvisable to arrange for the related classroom instruction.

More than 115 applications are on file in the chamber of commerce. This number is daily increasing and provides a splendid source of excellent material for this trade training course. Informative programs through the schools, parent-teacher associations and civic and social organizations in the community are presenting to the civic body the tremendous advantages of such an educational program. Young men can now pass directly from school, whether it be from grammar school, high school, or college, into major or basic industries in an intelligent and alive manner. No longer is the burdensome question "How can I start my son on the right track in life" one to be struggled with by anxious parents. Here young men can continue, as it were, their education to the end and be provided with a definite and worth-while work and place in the community.

From a survey made about a year ago, it would appear that between 350 and 400 apprentices can be placed in training in the industries of the community, on the present basis of employment. This maximum number, however, will be approached only gradually. Time must be given to individual plant organizations to adapt themselves and grow into a radically new program of this kind. New manufacturing establishments are being added to the program slowly, thus giving time to all engaged in the administration of this plan to expand in a safe and reasonable manner.

The East Chicago industrial community has determined to place itself on a firm foundation as regards the skilled personnel necessary for its continued industrial well being. The plan as adopted by the chamber of commerce has some successful experiences in other communities to justify it. Adaption naturally was necessary to meet the needs of this community, but the thorough preliminary study and careful organization of those participating in the movement, as well as their determination and earnestness, make it certain that this community will shortly place itself on a self-supporting basis as regards the training of its industrial personnel.

The Effect of Lead on the Mechanical Properties of a Complex Brass

By O. W. Ellis,* East Pittsburgh, Pa.

The question of the proportion of lead which can be allowed in a complex brass is one of considerable importance and one to which no final answer can be made. This is so because so much depends upon one's point of view. On the one hand are those who are concerned in producing an alloy of the highest grade and to whom lead is anathema. On the other hand, are those who are driven to the use of low grade materials in the manufacture of their alloys and who, on that account, are chiefly concerned in knowing to what limit they can go in so far as lead is concerned without running the risk of a damaged reputation for reliability. It is mainly to the latter that this contribution will prove of interest, since the experiments shortly to be described were carried out with the view of determining how the tensile properties of certain complex brasses were affected by variations in their contents of lead. As a result of these experiments, it was hoped that an upper limit of lead might be arrived at which would yet leave for service alloys of better mechanical quality than straight brass, though reasonably cheap.

It may be well to review some of the work that has already been accomplished in this connection, since it will serve to show that some justification for these experiments existed.

Solubility of Lead in Brass

In the first place, there appears to exist some difference of opinion as to the amount of lead which can be added to brass before it shows itself in the microstructure of the alloy as a separate constituent. Hudson and Bengough,[1] in connection with heat-treatment experiments on 70/30 brasses containing 0.25 per

*Research Metallurgist, Westinghouse Electric and Manufacturing Co.
[1] Journal, Institute of Metals, 1910, 4, 92.

cent, 0.005 per cent, and no lead respectively, state that "the presence of lead is indicated" in the microstructure "by small, more or less rounded, particles scattered throughout the crystals," making it clear that they believed lead to be all but insoluble in solid 70/30 brass. Parravano, Mazzetti and Moretti[2] fully confirm Hudson and Bengough in their belief, offering it as their opinion that practically no lead is held in solid solution by either the α or β phases of the copper-zinc system. Johnson[3] found lead to exist as a separate micro-constituent in a brass containing 66.54 per cent of copper, 0.78 per cent of tin and 0.54 per cent of lead.

Knight[4] also supports the view that lead is almost insoluble in brass and, therefore, appears as a separate constituent. Bunting[5] shows quite clearly that "in the case of an α or β brass containing 0.5 per cent lead, the greater proportion of this metal exists as undissolved globules" and remarks that "the solubility limit of an alloy of this description must be extremely small."

On the other hand, Altmayer and Guillet,[6] unless the author interprets them wrongly, believe that as much as about 0.9 per cent of lead is soluble in brass and, therefore, only such of this element as exceeds this amount can appear as a separate constituent in the microstructure of the alloy.

The author's view, however, accords with the majority of workers in this field. Certain it is that in all the lead-bearing complex brasses referred to below this element appears as a distinct entity.

Effect of Lead on the Mechanical Properties of the Straight Brasses

It is clear that the deleterious effect of lead on the ductility of brass has been understood for at least a hundred years. The quantitative effects of this element, however, were unknown until Sperry[7] published the results of his investigations on the effect of lead on 60/40 brass. These are reproduced in Fig. 1, the

[2] Gazz. chim. ital., 1914, 44, 475.
[3] Journal, Institute of Metals, 1917, 7, 20.
[4] Met. Ind., 1919, 83, 611.
[5] Journal, Institute of Metals, 1925, 33, 97.
[6] Metallurgie du Cuivre et Alliages du Cuivre, Paris, 1925, p. 528 ff.
[7] Trans. Amer. Inst. Min. Eng., 1897, 28, 176.

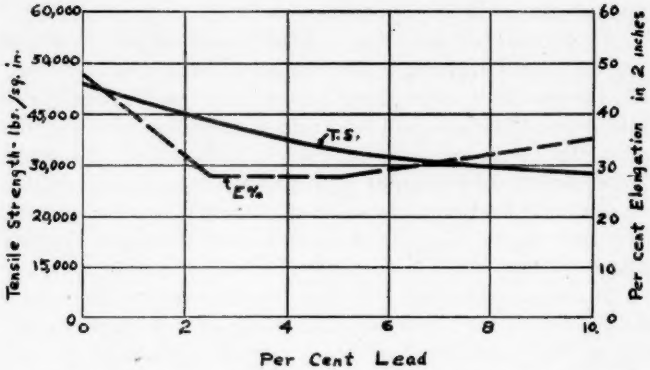

FIG. 1—GRAPH SHOWING EFFECT OF LEAD ON 60/40 BRASS—RESULTS OBTAINED BY SPERRY

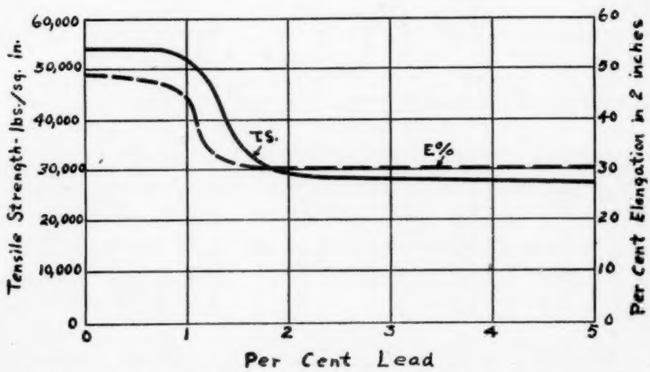

FIG. 2—GRAPH SHOWING EFFECT OF LEAD ON BRASS—RESULTS OBTAINED BY ATMAYER AND GUILLET

values in which refer to the cast materials tested by him. In all these alloys, it should be noted, the copper was sustained at about 60 per cent.

At a somewhat later date Guillet[8] published the results of his work in this connection. He concluded that (1) lead gradually lowers the tensile strength in brasses of the 70/30 and 60/40 types; (2) the elastic limit follows the same rule; (3) lead lowers the elongation and reduction of area appreciably, especially in brasses of the 60/40 type; (4) lead increases the brittleness and (5) lead does not alter the Brinell hardness appreciably. The results of his tests on brasses of the 60/40 type are collated in Table 1.

Altmayer and Guillet[9] also have published the results of work on the effect of lead on brass. Only those of their figures which apply to 60/40 brass need be quoted. (See Table 2.)

Table 1

GUILLET'S TESTS (1906) ON THE EFFECT OF LEAD ON 60/40 BRASS (AS CAST)

Copper Per Cent	Zinc Per Cent	Lead Per Cent	Tensile Strength	Elastic Limit	Elongation Per Cent	Per Cent Reduction of Area	Fremont Impact Test (kg. m.)	Brinell Hardness (1000 kg.)
60.0	40.0	nil	46,300	11,750	47.0	59.6	12	56
59.5	40.0	0.5	46,500	12,050	33.5	33.0	7	57
59.0	39.8	1.2	41,000	12,050	14.9	18.5	6	52
60.1	37.2	2.1	43,800	11,750	12.5	16.0	6	59
57.9	39.1	3.0	42,300	14,200	12.5	10.0	5	69

Table 2

ALTMAYER AND GUILLET'S TESTS (1925) ON THE EFFECT OF LEAD ON 60/40 BRASS (AS CAST)

Copper Per Cent	Lead Per Cent	Tensile Strength	Elastic Limit	Elongation Per Cent	Per Cent Reduction of Area	Fremont Impact	Brinell Hardness
59.45	0.57	53,500	10,000	48	40.0	12	61
59.33	0.86	53,200	9,430	47	42.3	13	57
59.28	1.03	51,300	9,570	44	35.9	10	61
59.94	1.13	34,400	....	37	35.0	..	..
58.98	1.32	42,300	6,810	23	24.0	6	53
59.74	1.46	35,400	....	31	36.4	..	..
59.22	2.27	34,200	....	35.5	36.4	..	..
58.41	3.21	21,300	....	9	13.9	..	..
59.75	3.23	29,000	....	30	30.5	..	..
59.34	5.05	27,800	....	31	28.5	..	..

According to Altmayer and Guillet[10] the samples referred to in Table 2 containing 0.57 per cent and 0.86 per cent of lead respectively showed no sign of lead in their microstructure. It

[8] Etude des Alliages Metalliques, Paris, 1906, pp. 661 ff.
[9] Loc. cit.
[10] Loc. cit.

is not surprising, therefore, to find that the mechanical properties of these alloys were practically unaffected by their content of lead. In fact, one would judge from their results that the relation between the tensile strength and the lead content of these alloys could quite reasonably be represented by such a curve as is shown in Fig. 2, while that between the elongation and the lead content could be represented by such a curve as is also shown in Fig. 2.

To those who disagree with Guillet in regard to the effect of lead on the microstructure of brass these results will appeal as open to question, since the effect of even a slight proportion of an insoluble constituent such as lead upon the mechanical

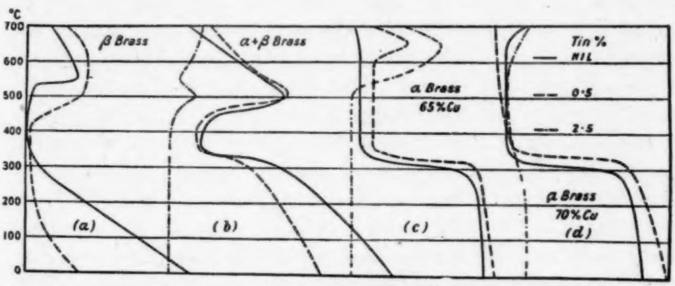

FIG. 3—EFFECTS OF LEAD ON THE BRITTLE RANGES OF BRASS (IZOD TEST) OBTAINED BY BUNTING

properties of an alloy containing it would be expected to be quite far-reaching.

In support of this expectation the results of Bunting's work[11] on the influence of lead on the brittle ranges of brass can be quoted. He shows clearly that the effect of even 0.5 per cent of lead upon the Izod figure of brass is quite profound, as will be appreciated on reference to Fig. 3, which is taken from the paper referred to above.

Effect of Lead on the Mechanical Properties of Complex Brasses

To those who hold the view that lead is practically insoluble in straight brass it would be surprising to find that the metal was any more soluble in a complex brass. Such indeed is the case.

[11] Loc. cit.

No evidence is forthcoming from the author's work to show that lead is anything more than slightly soluble in complex brass.

In so far as the mechanical properties of the complex brasses are concerned, one would, therefore, expect that lead would always have a deleterious effect. This apparently is the universal view, this view being clouded in some persons, however, by the economics of their situation. There have been statements based upon experiments to the effect that lead has apparently no influence upon the mechanical properties of complex brass, as, for example, that by Hirst[12], who found that "all mixtures" tested by him "contained lead and tin from 0.3 up to 1 per cent each, without any apparent difference in results." Then there are those who believe they have found lead to increase the ductility of brass, as, for example, Maclean[13], who, referring to the effect of lead on a manganese brass containing 56 per cent of copper, 41 per cent of zinc and 3 per cent of manganese, states that "though it was feared that a lead-free alloy might be very troublesome to machine, the writer wished to know the effect on the strength qualities of using the pure metals." The results showed "an improvement in elastic strength *but at the cost of the elongation.*" [14] The author's opinion is that in all these tests some undiscovered variable more potent than lead has served to vitiate the conclusions of the experimenters. There seems little reason for subscribing to any other view than that expressed by Corse and Hillman[15] in 1915; viz., "lead—is very detrimental to the finished brass."

This does not mean, of course, that a lead-bearing complex brass is of no value. It means simply that the same brass minus the lead would, from a mechanical point of view, be better.

The Author's Experiments on Chill Castings

In the author's experiments he has endeavored to determine the effect of adding lead to a series of alloys in which the ratio of copper to zinc varied from 1.28 to 1.32 (average 1.30) and which contained from 1.50 to 1.89 per cent of iron, 0.98 to 1.21 per cent of tin, 0.12 to 0.13 per cent of manganese and 0.13 to

[12] Journal, Institute of Metals, 1920, 23, 221.
[13] Ibid, 193.
[14] Author's italics.
[15] Met. Chem. Eng., 1914, 12, 113.

0.29 per cent of aluminum. These alloys were prepared in the following manner:

Approximately 6 pounds of copper were introduced into a graphite crucible together with the necessary weight of electrolytic iron. The crucible was introduced into an induction furnace and the charge melted under reducing conditions. When the copper and iron had become thoroughly alloyed, aluminum was added to the melt, then metallic manganese and tin. The melt was then thoroughly stirred. After this operation the crucible was removed from the furnace and the zinc incorporated in the molten alloy. The melt was poured at a temperature of 990°C ± 10°C into a chill mold, which gave ingots about 4½ inches long; 2¾ inches wide and 2½ inches deep. They approximated in cross-section to the A. S. T. M. standard ingot for manganese bronze (specification B7-24T), but were only ⅓ the length.

Analyses of the ingots were made with the results quoted in Table 3.

The microstructure of alloys 2, 3, and 5 is shown in Figs. 4, 5, and 6.

Table 3

No.	Copper Per Cent	Zinc Per Cent	Iron Per Cent	Tin Per Cent	Manganese Per Cent	Aluminum Per Cent	Lead Per Cent
1	54.60	42.32	1.55	1.21	0.12	0.16	0.04
2	54.91	41.71	1.56	0.98	0.13	0.20	0.51
3	54.44	41.88	1.50	1.00	0.12	0.13	0.93
4	53.65	41.60	1.55	1.08	0.12	0.15	1.85
5	52.59	41.14	1.76	1.15	0.13	0.29	2.94
6	52.87	40.39	1.89	1.08	0.12	0.17	3.48

The alloys will be seen to consist largely of the beta constituent.

From each of the ingots samples were cut for tensile test and for rolling experiments. The samples for rolling were in the form of plates 3 inches long, 1 inch wide and ½ inch thick. The tensile test samples were 0.505 inches diameter and had a gauge length of 2 inches.

The object of the rolling experiments, which were done in duplicate, was to determine the extent to which these alloys could be plastically deformed without failure. The plates referred to above were all treated in the same way. They were first reduced in one pass to a thickness of 0.45 inches (10 per cent reduction).

FIG. 4

FIG. 5

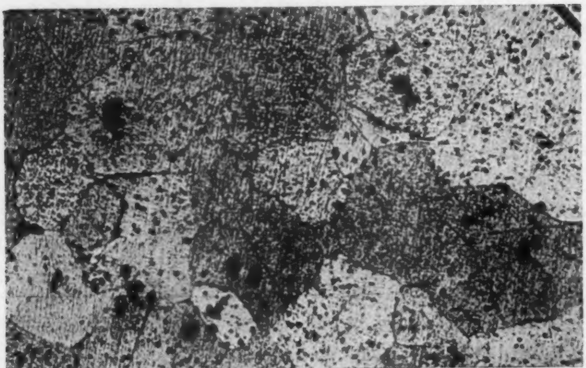

FIG. 6

MICROSTRUCTURES OF ALLOYS 2, 3, AND 5, RESPECTIVELY, OF TABLE 3, MAGNIFIED 250 DIAMETERS

All the alloys withstood this amount of cold work without failure. The samples were then reduced in one pass to a thickness of 0.40 inches, a further reduction of 10 per cent on the original thickness. This severe reduction (i. e. for these alloys) was successfully withstood by the first three alloys, but one of the samples from alloy 4, one of the samples from alloy 5 and both the samples from alloy 6 broke down completely on account of the internal stresses set up in them as a result of rolling. The failures observed were of the type shown in Fig. 7.

The remaining sound samples were now reduced in four passes to a thickness of 0.365 inches. The passes were as follows:

1.	0.400	0.385
2.	0.385	0.378
3.	0.378	0.369
4.	0.369	0.365

The total final reduction was about 27 per cent on the original thickness of the samples.

Table 4 shows the condition of the samples after this treatment:

FIG. 7

FIG. 8

Table 4

No.	Lead Per Cent	Condition
1	0.04	Both samples perfect.
2	0.51	One sample perfect, the other ruptured at the middle (see Fig. 8).
3	0.93	One sample almost perfect, the other broken (see Fig. 8).
4	1.85	Both samples broken, as in Fig. 8.

From the above it might be argued that the cold-rolling qualities of this complex brass are not seriously affected by quantities of lead up to about 1 per cent, but that any excess of lead over this amount is to be avoided. But any such argument would of necessity be based upon the outlook of the person wishing to use the alloy. The argument for the almost total exclusion of lead finds even more powerful support in these test results.

The results of the mechanical tests on these alloys are given in Table 5.

Table 5

No.	Limit of Proportionality	Yield Point	Tensile Strength	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area	Modulus $E \times 10^{-6}$
1	16,000	41,250	86,500	29.5	27	13.7
1	20,500	41,500	76,900	(*)	(*)	13.7†
1	.....	.....	87,850	25.5	27	...
1	.....	.....	88,200	26.0	28	...
2	20,500	40,500	75,350	(*)	(*)	13.5†
2	21,000	40,750	65,650	(*)	(*)	13.0†
2	.....	.....	73,000	(*)	(*)	...
2	.....	.....	80,050	15.0	16	...
3	(‡)	(‡)	(‡)	9.0	16	...
3	19,000	40,250	63,250	6.0	8	13.5†
3	.....	.....	77,150	(*)	(*)	(*)
3	.....	.....	77,150	9.5	12	(†)
4	19,500	40,000	72,250	(*)	(*)	13.6†
4	23,000	40,300	68,500	6.5	9	12.8†
4	.....	.....	75,000	9.5	10	...
4	.....	.....	59,750	3.4	5	...
5	16,000	42,750	74,500	(*)	(*)	13.1†
5	22,500	42,800	77,100	9.5	10	13.3
5	.....	.....	70,250	5.0	7	...
5	.....	.....	62,300	3.5	5	(†)
6	15,000	41,700	69,150	8.0	9	12.5†
6	15,500	41,800	69,500	(*)	(*)	13.1†
6	.....	.....	73,950	9.0	10	...
6	.....	.....	67,200	5.4	9	(†)

*Broke outside gauge length.
†Slight flaw in test samples.
‡Test O. K., but breaking load, etc., not noted.

It will be noted that four test samples were turned from each casting. Two of these samples were tested completely, measurements of the limit of proportionality, the yield point, and the longitudinal modulus of elasticity being made. Two were tested for strength and ductility alone. For these tests the author

is indebted to T. F. Hengstenberg of the Mechanics' Section of the Research Department of the W. E. & M. Co.

A number of the samples broke outside the gauge length; some exhibited flaws in the fracture. This is considered worthy of remark since no less than 74 complex brasses free from lead, made under identically the same conditions, have been tested and only one case of a flaw or of a break outside the gauge length has been recorded. One might infer that lead has played some part in producing these defects.

If, of the above tests, those are left out of consideration which refer to defective test samples the results shown in Table 6 are obtained:

Table 6

No.	Lead Per Cent	Tensile Strength	Per Cent Elongation on 2 Inches	Per Cent Reduction of Area
1	0.04	87,500	27.3	27
2	0.51	80,100	15.0	16
3	0.93	77,200	9.0	11
4	1.85	75,000	9.5	10
5	2.94	73,700	7.2	9
6	3.48	74,000	9.0	10

These results are shown graphically in Fig. 9.

A consideration of all these results leads to the following conclusions:

1. Lead has but little effect on the modulus of elasticity, E, of this complex brass.

2. Lead has but little effect on the limit of proportionality of this alloy—possibly, however, the 3.48 per cent alloy is weaker in this regard than the others.

3. Lead has a definite effect on the tensile strength of this alloy, lowering it rapidly at first and then less rapidly as the lead content passes about 1 per cent.

4. Lead materially reduces the ductility of this alloy, both the elongation and reduction of area of the test samples being distinctly affected by the first additions of this element.

Further confirmation of these results have been obtained by the author on a somewhat different alloy of the same general type. In the case of this alloy tests were made on samples poured into chill molds of smaller cross-section—about 1¼ inches square and 6 inches long. The alloy was melted under normal foundry conditions in a furnace of the oil-burning type. The molds were filled by metal teemed from 200 pound ladles. The analyses of the alloys examined are given in Table 7.

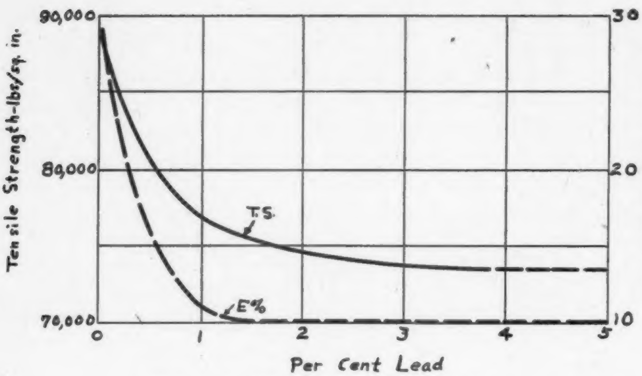

FIG. 9—GRAPHS OF DATA OF TABLE 6

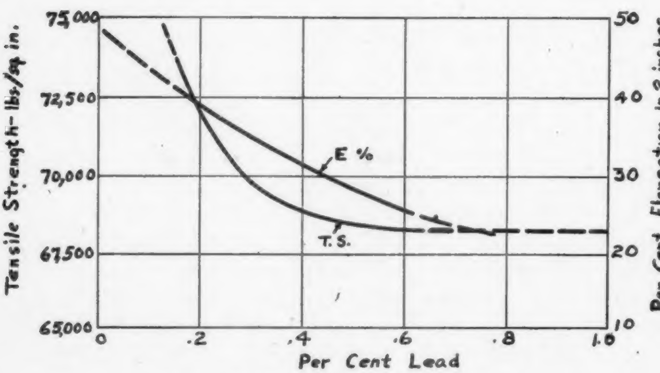

FIG. 10—GRAPHS OF DATA OF TABLE 8

Table 7

No.	Per Cent Copper	Per Cent Zinc	Per Cent Tin	Per Cent Iron	Per Cent Aluminum	Per Cent Manganese	Per Cent Lead
7	58.58	39.40	0.58	0.94	0.10	0.25	0.15
8	59.12	38.50	0.56	0.98	0.26	0.30	0.28
9	59.10	38.41	0.62	0.94	0.24	0.29	0.40
10	59.38	38.40	0.50	0.82	0.16	0.27	0.47
11	59.12	38.36	0.52	0.88	0.18	0.34	0.60

In the case of these alloys, the ratio of copper to zinc varies from 1.49 to 1.54 (average 1.53), that is to say it is 0.21 (average) higher than in the case of the alloys referred to above (Table 1). The tin and iron contents of the alloys of this series are somewhat less than that of the first series, the aluminum and manganese contents somewhat higher. The difference in analysis and particularly in the copper-zinc ratio and the tin content of the two series of alloys accounts in the main for the difference in mechanical properties. The mechanical properties of the second series are given in Table 8.

Table 8*

No.	Lead Per Cent	Tensile Strength	Elongation Per Cent	Per Cent Reduction of Area
7	0.15	74,000	36.0	41.6
8	0.28	70,200	32.1	36.6
9	0.40	68,950	28.8	31.3
10	0.47	69,350	27.6	30.8
11	0.60	68,000	20.6	26.1

*These results represent average values for three tests.

These results are shown graphically in Fig. 10, and serve to confirm very definitely the findings stated in the third and fourth paragraphs of the conclusions stated above.

The Effect of Lead on Sand Castings

So far attention has been directed to chill castings only. The question arises as to whether lead has so profound an effect on sand castings as on chill castings. This the author has so far not determined. Such tests as he has been able to make seem to bear out the conclusion that other factors than lead content are more potent in their effect upon the mechanical properties of sand castings of complex brass such as has been discussed above. The average of duplicate tests on a series of four sand cast alloys containing 0.14 ± 0.02 per cent of lead and otherwise very similar to alloy 7 of Table 5 was as follows:

Tensile strength ....65,400 lbs. sq. in.
Elongation 33.4%
Reduction of area..............32.8%

The average of duplicate tests on two sand-cast alloys containing 0.35 ± 0.01 per cent of lead and likewise similar to the alloys in Table 5 was as follows:

Tensile strength ....68,032 lbs. sq. in.
Elongation 35.6%
Reduction of area..............32.3%

The latter results are on the whole better than the former, despite the fact that they refer to an alloy containing more than twice the amount of lead. One might judge, in fact, that lead was beneficial in this case, whereas the truth appears to be that the effect of lead is completely masked by other factors having a more powerful influence on the mechanical condition of the castings.

Conclusion

The author's work thus leaves the question of the effect of lead on complex brasses partly unanswered. He believes that he has proved conclusively that lead has an important effect on the mechanical properties of complex brass cast in chill. But only a statistical study of many tests could answer the question in regard to complex brasses in the form of sand castings.

One thing the author's work has made clear is that both those who assert that lead is inoccuous in complex brass, as for example, Hirst[16], Maclean[17], and McKinney[18], and those who claim that lead should, as far as possible, be excluded, are probably right. It is evident that where chill castings of all types or sand castings of very high strength are looked for lead must always be viewed with suspicion. However, where all manner of scrap has to be used in the manufacture of dependable sand castings of medium strength (say 65,000 lbs. sq. in. to 75,000 lbs. sq. in.) lead up to 0.5 per cent at any rate appears to be without appreciable effect upon the tensile properties. In so far as resistance to shock is concerned, Bunting's work[19] has shown that lead is deleterious; it is of interest to note, however, how much punishment can be given lead-bearing material as in rolling. Nevertheless, despite the relatively good showing of lead-bearing material in this connection the author feels that in a complex brass that is to resist shock, a minimum of lead should be specified.

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[16] Loc cit.
[17] Loc cit.
[18] Trans. Amer. Inst. Min. Met. Eng., 1919, 60, 374.
[19] Loc cit.

Cutting Costs and Stabilizing Labor

By A. D. Lynch,* Mansfield, Ohio

To attempt to prepare a paper along the lines that this one must follow for delivery to such a group as The American Foundrymen's Association presents many difficulties.

Among the membership of the association are undoubtedly plants representing almost every stage of development of industrial relations work. From the plant that has no organized set-up for work of this kind to the ones where most successful work has been done and because of this wide difference in development in the various member plants there must exist a wide variation of opinion as to what constitutes a proper program of industrial relation work, and even as to the desirability or practicability of such programs.

Some twenty or twenty-five years ago, Emerson, Taylor, and a few other advanced thinkers along industrial lines first introduced to industrial management certain principles of management that became known to industry as "Scientific Management." These principles were fundamentally so simple and so obvious that all might easily understand and apply them, and within the next few years industry was overrun with "efficiency experts" or "scientific management experts" most of whom did understand and could apply these new ideas and principles but most of whom also did not know or observe the well-established and fundamentally sound practices of management which were still necessary as an accompanying program to their "scientific management." As a result, although the ideas and principles are still in daily use in all progressive plants, the terms "efficiency expert" and "scientific management" have fallen into ill repute with industrial managers.

Now somewhat the same thing happened in industrial relations work. Much successful work along these lines had been done in larger plants for a good many years but it remained for

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the abnormal conditions confronting industrial management during the period of the World War and the years immediately following to bring many more industries into some sort of industrial relations or personnel work. With the demand for this kind of work came also the crop of theorists and self-styled experts with a multitude of untried theories that sounded plausible but were impractical in application, and many industrial managers spent time and money on them and reaped only discouragement and disappointment.

That is one reason why this paper is not titled "Cutting Costs and Stabilizing Labor by Personnel Work" or by "Industrial Relations Work." The other reason is that common or horse sense best describes what is needed in such a program.

It hardly seems necessary in talking to an industrial group such as the American Foundrymen's Association to make any explanation of the cost of labor turn-over. It should suffice to say that industry generally has recognized that the constant changing of help with the attendant cost of extra supervision in "breaking in" the new man, loss of production, spoilage of materials, breakage and damage to machinery and equipment, payment of day-work on jobs normally done piece-work and many other factors constitutes the greatest waste in industry today. The difference in performance that may be had from the same group of people, in one case, interested in the success of the company for whom they are working, and sufficiently acquainted with the policies and requirements of the business to be able to really work intelligently, and in the other case, just working for the company, is perhaps not so well recognized, but will be found to offer a most fertile field for cost reductions.

Fundamentals in Working Conditions

If labor is to be stabilized in any plant the first and most important requisite is that the fundamental working conditions must be made such that men will want to work there in preference to other plants; the day is long past when anything else will do, you cannot coerce or force workers to remain at work, you simply must make your conditions such that they will wish to stay.

The things I would class as fundamental in working condi-

tions are not many, but each is important. I shall enumerate them first and discuss each briefly afterwards.

1. Buildings and Surroundings
2. Machinery and Equipment
3. Compensation
4. Continuity of Work
5. Proper Leadership

Buildings should be kept in good physical condition, should be properly heated, lighted and ventilated, and the buildings themselves and the surroundings should be kept clean and orderly. It is not reasonable to expect good, careful work in surroundings that are disorderly and dirty. It is not always possible to have nice new buildings, the earnings of the business may not seem to warrant the expense necessary to put buildings in such shape that they would be an asset in keeping people at work, but if the condition of your plant makes it a less desirable place to work than others in your locality, you may be sure that, in general, you are getting the workers that the other plants do not want, or cannot use, and the cost of inefficient work and turn-over would, if eliminated, soon pay for whatever your buildings need.

Machinery and equipment, tools, patterns, etc., must be properly fitted for the type of work to be done and must be kept in good condition. It may be possible to keep second-rate mechanics, or disinterested workers performing with poor equipment, but you will not for long keep a good mechanic interested and taking a pride in his workmanship unless you provide equipment with which he can do good work. Even the ancient Egyptians discovered this fact when they tried to force the Israelites to make bricks without straw. From an economic standpoint entirely aside from its effect on people, you cannot afford to operate with machinery or equipment that is not the best type for your work and that is not constantly kept in good condition and properly safeguarded to prevent accidents.

Many factors over which management of the individual plant has no direct control will help to determine basic wage scales. The part of management should be to see that wages within the plant are equitable. High spots and low spots, unfairness within a plant in compensation will cause more dissatisfaction and lose you more

help that a basically low wage if such be necessary in the business. If your basic scale is so low as to be a determining factor in your ability to secure and keep good interested workers, then almost regardless of what your competitive situation may be, and your need of keeping costs down, you will find that a wage basis that will reduce turn-over will, while seemingly higher, eventually reduce direct labor costs.

Irregularity of employment is perhaps the greatest contributing factor in the economic difficulties of workers in general. True, many of them make their own economic troubles by failure to remain at jobs they have, but industry forces the condition on many more by seasonal employment. It is recognized, of course, that certain industries will always require more people at certain seasons of the year, but in many cases fluctuations in employment are caused by failure on the part of management to properly plan schedules and even out peaks and valleys in their program of production.

The amount of productive activity required will always depend on factors outside the control of an individual plant, such as general business and market conditions covering the specific product, but much can be done by the study of past performance and requirements to stabilize your working force. Certainly it is desirable to avoid forcing labor turn-over upon your own plant and it is just as certain that workers in your locality of the better type will avoid your plant if it has the reputation of giving seasonal employment.

Leadership, the last of these five fundamental requirements in set-up, I would class as the most important. The best working conditions, steady employment, good wages, all the additional things that management might add in policy or that might be provided as accessories, would not make of any plant a really desirable place to work unless the foreman or department head, the company representative directly in supervisory control of people, was of the right sort and managed his people in the right way.

The problem of foremanship is within itself a major part of your problems both of labor turn-over and cost of production. The answer to the problem lies first in the selection of your foremen and second in foremanship training. I have placed the selection of the individual as more important than the training. If you

wished to enter a horse in a race you would not spend time and money training a cart horse. The training, however, is essential even with the best of material to start with.

Attributes for Foremanship

What are the requisite characteristics and attributes for foremanship? They are many. I shall not attempt to enumerate all of them but I think it is worth while to indicate a few of them and try to show why they are essential.

I would place first knowledge or skill pertaining to the kind of work to be done in the department to be supervised. It may be possible to undertake foremanship of work that is new or different and to successfully maintain such a position and leadership if the candidate fairly quickly assimilates the necessary knowledge or skill, but a foreman cannot for any great period hold the respect and good will of his workers if he is trying to give instructions on and supervise work which he does not fully understand or which he could not do himself. He cannot keep the knowledge of such a short-coming from his people. If he is to really succeed as a foreman he must know more about the work that is done in the department than any one else in the department.

Second, as an attribute for leadership I would list "honesty." I do not mean just that degree or kind of honesty that would prevent one from taking something that belonged to another or from telling an untruth or mis-stating facts. Honesty in its broader sense goes farther than that. Your foreman should have an honesty of purpose in all that he does and in his relationship with his own people and with those in other departments with whom he makes business contacts that would at all times be such that no one would ever question his motives or doubt his sincerity, and he must remember at all times that it is easy for a person to fool one's self. It is more difficult to fool those whom he works for. It is still more difficult to fool those whom he works coordinately with and it is almost impossible to fool those who work under his direction.

Third, I would put "fairness." Few things will lose for a foreman as quickly the good-will and friendship of his people as a suspicion or feeling that his decisions or his distribution of work or other acts as a foreman are biased or unfair or that favoritism

or spite influence him in the conduct of his department, and he must remember that his conduct of his department must be above even the suspicion of unfairness, for the suspicion and the resulting talk can be as hard to overcome as a record of absolute unfairness.

Fourth, I would put "sympathy," the ability to understand and have a feeling of kindly helpfulness for the troubles and disappointments of his fellow-man, and a real desire to help him. A foreman in direct charge of people will find this attribute will do much to draw people to him and to win and hold their loyalty and support.

Fifth, I would place "judgment" and in its use I, of course, mean good judgment. The very nature of a foreman's position, in charge of work and supervision of people, will continually make it necessary for him to make decisions or judgments on facts, on work, and on actions of people. If these decisions or judgments are not sound, he will not be able to keep the confidence of his people. The only basis for sound and correct judgments is a thorough knowledge of the job and of his people and of the facts relating to the question at hand, plus a background of experience and knowledge of the policies of his management and the decisions and judgments he has had from his superiors in the organization on like questions. A foreman will find that while it is fine and perhaps impressive to be able to make decisions and render judgments promptly it will always prove more satisfactory to take more time, if necessary, but be sure his decisions are sound when made.

Sixth, I would place "open-mindedness." A foreman should not disregard the opinions of others. He must have sufficient confidence in himself to be able to act on his own judgments, but he must be sure that in forming such judgments he has had all the facts and opinions essential to making a proper decision. He must not be influenced by racial, religious or political differences. The very cornerstone of our government is laid in the rights of the individual and a foreman's position does not carry the prerogative to dictate to his people regarding their personal affairs. Organized industry and business need the stimulation of all the ideas of all its people all the time. The right attitude on the part of all foremen in giving proper hearing and consideration to

any and all ideas or suggestions that his people may have will do more to bring this latent source of power into use than any plan of payment for suggestions.

Seventh, and last, I would place "human understanding." By that I mean the ability or capacity to understand and sympathize with the hopes, aspirations and fears of his people, and a real desire to be helpful to them. This attribute can be gained only when there is present in the foreman a real spirit of altruism and by the accumulation of knowledge and experience gained by his contacts with humanity at large. If he does not have such an attitude toward people in general it will be most difficult, if not impossible, to successfully simulate it toward those with whom he works.

These are not all the personal characteristics that might be listed, but I think they are the most important ones and I know that they are essential. If your foremen do not have these things and are not using them on the job, then part of your labor turnover is due directly to foremanship.

Foremanship Training

Having foremen or candidates for foremanship who have these qualifications, the next requisite is foremanship training, and the first and most important part of that training is instruction in the facts, figures, problems and policies of the company and its business.

It is manifestly unfair to place a foreman in charge of a department, hold him responsible for people, production, costs and all other details and problems of his department and fail to give him all the facts and figures essential to an intelligent operation of the department or the policies of the company as regards people, if there be one, yet the greater part of foremen in industry today are working under such conditions; they know what quantity of production is required but rarely know just why the quality requirements are what they are. It is very seldom that foremen know costs and how they are made up and still less often that definite policies have been given them for handling of people. The first step in training, therefore, is to give them these things fairly and fully. If you are not willing, or not in a position to

give all the facts, it is better not to start such a program for any feeling of suspicion that pertinent facts are being withheld will have the wrong effect on your foremen.

Having supplied this training, the next step is to train your foremen in some of the fundamentals of handling people. Surely your foremen are already handling people, assigning work, giving instruction, hiring and discharging, but are they doing these things in a manner that secures for the business the best performance of the individual worker? Your foremen should be trained to do many things properly in the handling of people. Some of the more important of these are:

1. Placing men according to their ability.
2. Giving instructions properly.
3. Managing individual workers according to their temperament.
4. Delegating and supervising work properly.
5. Compensating fairly and proportionately.
6. Setting a proper example for his people.
7. Maintaining discipline.
8. Cultivating an unselfish desire to help his people.
9. Developing his own personal character.

I will not take the time to discuss the importance of each of these functions in the handling of people. I believe it is self-evident that they are essential requirements of good foremanship and I think we will all agree that it is part of management's duty to train foremen to do these things properly. If you will analyze the foremen as a group in your own or any other plant, and consider what their training and experience has been before coming to foremanship rank you will readily understand that training along these lines is necessary.

These are the foundations and fundamentals of a proper program of industrial relations or personnel work. If you do nothing more but do all these things well you will not have an unsatisfactory record of labor turn-over. Failure to have or do these things is a basic cause of most of the dissatisfaction which causes people to leave work.

Industrial Relations Work

The additional things that may be done are what most people call or consider personnel work or industrial relations work. I refer to club rooms, gymnasiums, cafeterias, athletic grounds, company picnics, parties and entertainments, loan and home building plans, etc., and all these things properly administered do have a proper place in such a program but they are only the frills and trimmings. The real operative part of your program must remain in your fundamental working conditions and in your foremanship.

These accessories to your program are valuable if they are provided and administered in such a manner as to make working conditions and surroundings more agreeable. You will find it good policy, however, to have all service of a personal nature handled by or through the foreman and not by a personnel manager or someone from such a department coming between foremen and men. Your foreman is, in fact, your keyman. The more fully you make it possible for him to function fully as the complete manager of people and work in his department, the better your results will be.

I shall not take more time to discuss remedies for turn-over. Just as soon as management honestly accepts the fact that those who work in their plants are human beings with the same rights, feelings, hopes and aspirations that those engaged in management have and conduct their business accordingly, we will have no labor turn-over problem in industry.

Training Program for Workers

I wish briefly to discuss the possibilities of better performance that lie in educational or training programs for workers. Consider for a moment what the trend of industrial development for the past fifty years has done to the worker. Formerly each worker was an artisan or tradesman. He generally made a complete article almost entirely with his own hands. Today most of them do an operation designated by a number on a part or piece whose final use or purpose they do not even know.

Industry has taken from the worker the joy of creation that is inherent in all of us and has given him routine monotony at high speed. What, then, can be done to correct this condition?

Management must show the worker first the economic necessity for this change in procedure, and second his place in the present scheme of production. Management knows that competition forced the change in methods, students of industrial economy know that only consolidation of large interests with sufficient capital, making possible mass production, has given us the volume and cost of product that we have today and that these things have been a greater boon to the worker than to management, for they have made possible a standard of living and an enjoyment of facilities, yes, even luxuries, for our workers that could have been possible under no other condition.

Management can show all these things to people and by so doing can to a great degree change the worker's viewpoint and secure a cooperation that is impossible so long as the worker feels that management alone has forced on him all these changes and that management alone has profited by them, for he has not had the training or education that fits him to analyze these things for himself.

I realize that it is easy to make such statements as the foregoing and that many will doubt the feasibility of such a program. The best answer I can give to any having such doubts is that I know of many places where it has been done and the results have proved most beneficial.

At our own plant we started some years ago to hold classes on company time and explain these things to our workers. The last program of this nature was held during October and November, 1927. We have approximately 1,000 workers in the plant. These were divided into six groups, by departments, and eight talks were given to each group as follows:

The personnel manager talked on the company's policies with people.

The production manager talked on our production program.

The technical superintendent on the need for technical control in processing materials.

The development engineer on development of new devices.

The chief engineer on our engineering problems with our customers.

The sales manager on the distribution and uses of our product and our sales problems.

The cost manager explained the method and manner of making up costs, using charts to show every item of overhead, even including selling expense, and showing final cost compared to selling prices taken from shipping sheets that all could see.

During the same months that this program was being conducted we took our workers on personally conducted tours of the plant. They were taken through in groups of eight, with a member of the manufacturing superintendent's staff as a guide and every effort was made to explain all processes and the requirements of each department and the necessity for proper inter-department relations.

We know definitely that all our people are not only better workers because of a better understanding of the requirements of our business, but they are also more interested workers because of the interest management has shown in them.

I know personally that all these things bring results. I am not giving you the theories of one who is in any way a fanatic on human relations. I have been in personnel work for just two years. For twenty-two years previous to that I was a cost accountant, for nine years with the Western Electric Company and for thirteen years at the Ohio Brass Company, and I am telling facts of which I am absolutely sure when I say that proper human relations in your plant will immediately be reflected in the cost of your product.

The cost of labor turn-over is so well recognized and so definitely a factor in your cost of production, and the efficiency of your working force is so vital a factor in the economic existence of your plant, that you cannot hope to compete with plants having a favorable turn-over record and an interested intelligent working force unless you can also have these things. You may theorize and experiment as much as you please or can afford; in the end you will have to make your plant conditions and your foremanship such that people will actually want to work for you and you will have to keep them really interested in the things they are doing or you will not get the results you desire and need.

General Status of Foundry-Coke Specifications

By W. A. Selvig,[1] Pittsburgh, Pa.

A committee on standard specifications of foundry coke was formed in 1905 by the American Society for Testing Materials. Shortly after, the committee enlarged the scope of its work to include blast-furnace coke. The first report of the committee,[2] presented in 1906, outlines a comprehensive program, as follows:

It seems that for several years a change has been gradually taking place in the coke situation of the country. A number of new fields are being drawn upon for coke-making purposes and in addition new methods of operation are being applied. The result is that the so-called 72-hour coke made in the old beehive oven is no longer descriptive of what is being shipped under this name, and the best-looking portions of every charge are put aside for foundry purposes and shipped as the 72-hour article. As the results obtained in the foundry with 48-hour, or even 24-hour coke thus selected, are equal to those from the straight 72-hour variety, it would seem desirable to eliminate this deceptive provision from specifications.

The advent of by-product coke in the foundry industry has further modified the existing conception of what a foundry coke should look like, and hence your committee feels that in this time of transition it would be unwise to put forth a definite specification based entirely on experience with the Connellsville product, at least until further studies in connection with the production of coke has been made, thus doing justice to the maker as well as the consumer.

These additional studies may be summarized as follows:

Investigations covering the proper sampling of coke. All the specifications in the world will be useless unless a properly representative sample is obtained.

Next, the chemical analysis of coke. This is to include what is wanted in the examination as well as the preparation of standard methods for determining the separate constituents. Thus the question of moisture determination, the total sulphur, the sulphur in the ash and the effect the latter is supposed to have on the iron under varying melting conditions.

Next come the physical tests of coke. Just what is required along this line, and what may be omitted. Thus, a moment of thought will show how worthless the crushing strength of a cube, cut from a lump, is for representing a shipment. Or for that matter, 100 such cubes, no two pieces of the various parts of a charge being alike.

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[1] Associate chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines. Secretary, Committee D-5, on Coal and Coke, American Society for Testing Materials.

[2] Report of Committee J, on Standard Specifications for Coke, Proceedings, American Society for Testing Materials, Vol. 6 (1906), pp. 99-100.

Finally a study should be made of the behavior of coke under what may be called service tests; that is to say, the devising of methods showing how it would behave in descending the cupola or blast furnace. Also just what happens to a coke in being unloaded several times with a fairly high drop, etc.

All these matters enumerated above will naturally form the basis of a set of specifications which will give a positive assurance to the purchaser that whatever he does with the coke he buys, good results are possible when the specifications have been met.

Sampling and Analysis

The coke committee logically first considered the standardization of methods of sampling and analysis of coke. The committee, in collaboration with a joint committee on coal analysis of the American Society for Testing Materials and the American Chemical Society, and with a committee on coke analysis of the American Foundrymen's Association, prepared methods for analysis of coke which were published in 1915 as tentative standards.[3] These methods include the preparation of the laboratory sample and the determination of moisture, ash, volatile matter, fixed carbon (by difference), sulfur, and phosphorus; they were accepted in 1918 by the American Society for Testing Materials as standard methods.[4] The preparation of these standard methods was a distinct step forward towards the drawing up of specifications, as many of the determinations made are empirical and require careful standardization to be of much value for use in specifications. The standard methods of analysis are now generally recognized as satisfactory and should be used in specifications covering the analysis of foundry coke. They have been revised from time to time and are now published as Standard Methods of Laboratory Sampling and Analysis of Coal and Coke in Part II of the 1927 Book of A. S. T. M. Standards.

A. S. T. M. Specifications for Foundry Coke

In 1915 the coke committee presented tentative specifications for foundry coke, which were later accepted as standard.[5] These specifications cover the method for sampling, preparation of the sample for analysis, and limits of chemical composition. Each carload of coke, or its equivalent, is specified as a unit for sam-

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[3] Proceedings, American Society for Testing Materials, Part I, 1916, pp. 551-563.
[4] Standards, American Society for Testing Materials, 1918, pp. 709-720.
[5] Standard Specifications for Foundry Coke, A. S. T. M. Standards, 1927, Part II, pp. 524-526.

pling. A sample of not less than one cubic foot is taken from the exposed surface of the car, by breaking off with a hammer pieces approximately the size of a walnut, at regular intervals over the surface of the exposed coke. Specific directions are given for crushing and reducing the sample to not less than 5 pounds for transportation to the laboratory. Directions are given for collecting a special moisture sample.

In regard to chemical composition it is specified that the dry coke shall not exceed the following limits in chemical composition:

Constituent		Per cent
Volatile matter	Not over	2.0
Fixed carbon	Not under	86.0
Ash	Not over	12.0
Sulfur	Not over	1.0

The specifications state that the purchaser shall have the option of deducting the moisture in excess of three per cent from the weight of the coke, provided that the car is weighed at the time of sampling.

The method of collecting a one-cubic foot gross sample from the surface of coke exposed in a car can scarcely be considered good sampling procedure. Good sampling would require the collection of a much larger gross sample taken at regular intervals while unloading the coke. The committee recognized this fact in presenting its report[6] but justified the method for several practical reasons: (1) The crushing and reduction of several hundred pounds of coke necessitates the use of mechanical crushers, which are seldom available at the point of sampling; and (2) sampling while unloading the coke is feasible only when the coke is purchased under a system of premiums and penalties, which system, according to the experience of the committee, the trade was not willing to accept at that time (1915). It was also stated that as the only acceptable form of specification is one based on maximum and minimum limits of chemical composition with the privilege of rejection when these limits are exceeded, it seemed essential to take the sample from the exposed surface of the car so that the car could be rejected before unloading in

[6] Report of Committee D-6 on Standard Specifications for Coke. Proceedings, American Society for Testing Materials, 1915, Part I, pp. 359-361.

case the coke did not conform to the specifications. Coke that fails to conform to the limits of chemical composition will be rejected and the seller notified within five working days from the date of sampling.

The specifications state that in case of disagreement between buyer and seller, an independent chemist, mutually agreed upon, shall be employed to sample and analyze the coke, the cost to be borne by the party at fault. The resample shall be taken and prepared as prescribed before, except that the minimum quantity of gross sample shall be not less than 1 bushel in volume, taken at intervals of 18 inches on six equidistant lines parallel to the side of the car.

The writer knows of no published data concerning the reliability of collecting coke samples from the exposed surface of a car. Such a method would appear to be satisfactory only in sampling homogeneous substances, but coke can hardly be considered in that class. Chemical analyses based on nonrepresentative samples are often worse than useless, as they are misleading. Some experimental coke sampling should be conducted to obtain information showing how analyses of samples collected by this method compare with analyses of samples collected by taking large gross samples of several hundred pounds as the car is unloaded. If anyone has made such comparative sampling tests, the writer would like to learn the results.

Various Foundry-Coke Specifications

A number of foundry-coke specifications are listed in the National Directory of Commodity Specifications.[7] For comparative purposes the limits of chemical composition of these specifications are given in Table 1.

One of the specifications given in Table 1 is that of a large manufacturer, eight are those of railroad companies, and one is that of the Navy Department. These specifications are almost similar in regard to chemical composition, which indicates that there should be no special difficulty in getting various companies to agree to the same specifications. Only two of the specifications have a limit for phosphorus content. One limits phos-

[7] National Directory of Commodity Specifications, 1925, Bureau of Standards, pp. 102-103.

phorus to a maximum of 0.025 per cent, the other to 0.05 per cent. In regard to size, some of the specifications state that the pieces shall be large with as little breeze as possible; others that the coke shall contain no fines or no breeze. Two of the specifications state that practically none of the coke shall pass through a 2-inch ring; another that all shall be retained on a 2½-inch screen.

Physical Properties of Coke

When we attempt to include the optimum physical properties of coke in specifications, we are up against a real problem due to a lack of definite knowledge of the relation of these properties to the performance of the coke in the cupola. Coke is not a homo-

Table 1

LIMITS OF CHEMICAL COMPOSITION OF VARIOUS FOUNDRY-COKE SPECIFICATIONS

Company Designation	Maximum Volatile Matter	Minimum Fixed Carbon	Maximum Ash	Maximum Sulfur	Maximum Moisture
A. S. T. M.	2.0	86.0	12.0	1.0	3.0
1	2.0	86.0	12.0	1.0	1.5
2	2.0	...	12.0	1.0	0.5
3	2.0	87.0	10.0	1.0	..
4	..	...	12.0	1.0	..
5	2.0	...	12.0	1.0	..
6	1.3	...	11.0	0.8	..
7	2.0	...	12.0	1.0	..
8	1.0	85.8	10.0	1.3	2.0
9	1.0	85.8	10.0	1.3	2.0
10	3.0	86.0	12.0	1.0	..

geneous substance, and variations not only occur between different pieces from the same oven charge but also different portions of the same piece will show differences in structure. As is well known, the first by-product coke was condemned by many for metallurgical use because it lacked the silvery luster of beehive coke. There unquestionably is a considerable variation in physical properties of coke due to inherent differences in the coals available for making the coke and in the coking process itself.

Our best coking coals are limited in quantity, as they have been heavily drawn upon in the past. The rapid development of the by-product coking process has made available for use coals that only a short time ago were considered unsuitable for making metallurgical coke. It is common practice to mix low and high volatile coals in order to increase the size and strength of the

coke. Improvements in coke-oven design have made possible the coking of straight high-volatile coal, and a large amount of metallurgical coke is now made from coals ranging from 28 to 35 per cent volatile matter.

It is well known that blast furnaces have been and are now operated successfully on coke whose physical characteristics differ widely from the common conception of what should constitute good furnace coke. I assume that this is true also in the operation of a cupola; good results may be obtained with coke of varying physical properties provided that the foundryman learns how to use it to best advantage. It is evident that the foundryman should select the best coke available without imposing any needless requirements which would tend to reduce the oven output or seriously affect the gas and by-product yield. Moreover, the coke producer is naturally limited as to the coals economically available to him for coke-making. It is well understood that the character of the coke produced largely depends upon the type of coal charged into the ovens. These points are presented for consideration, as the problem of coke specifications should be approached without prejudice.

Before attempting to write specifications covering various physical properties of coke, it is essential that definite information should be available as to how these variations affect the coke in practical use. Apparently there are differences in the performance characteristics of various cokes that are good cokes in as far as chemical composition is concerned. Coke may be light or heavy, porous or dense, soft or hard, brittle or tough, weak and friable, massive blocky pieces, or small fingery pieces full of checks. The committee on coal and coke of the American Society for Testing Materials has standardized and is standardizing methods of physical testing in most common use for metallurgical coke. Such testing is empirical, and to be of value it is necessary that the methods be carefully standardized if the results are to be used in determining how the various physical properties of coke affect its performance in actual use. If we can successfully correlate the results of physical tests with performance in the cupola, we can approach the question of specifications with some intelligence.

Porosity, True and Apparent Specific Gravity

By porosity is meant the percentage of the volume of the coke which is occupied by cells. This value usually varies from 40 to 60 per cent; the average is about 50 per cent. The specifications of the Navy Department[8] for foundry coke require not less than 50 per cent by volume of cell space.

Porosity is calculated from the apparent specific gravity of the moisture-free lump coke and the true specific gravity of moisture-free coke pulverized to pass a 200-mesh sieve. It is usually computed as follows:

$$\text{Percentage of cell space} = 100 - 100\,\frac{\text{Apparent specific gravity.}}{\text{True specific gravity.}}$$

This method of test has been standardized by the American Society for Testing Materials.[9]

By true specific gravity is meant the specific gravity of the carbonaceous material and inorganic matter making up the cell walls of the coke. Apparent specific gravity is the specific gravity of the coke substance plus the cells. Metallurgical cokes usually show a true specific gravity ranging from 1.8 to 2.1, and an apparent specific gravity of 0.8 to 1.15.

True specific gravity is influenced by the coking temperature, rank of coal, and percentage of ash in the coke. Some believe that the combustibility of coke increases as the true specific gravity decreases. The apparent specific gravity obviously depends upon the true specific gravity and the porosity of the coke. One of the specifications included in Table 1 requires that the apparent specific gravity shall not be less than 0.8.

Shatter Test

The shatter test was designed to give a measure of the mechanical strength of coke and should indicate the probable breakage of coke on handling. The test has been standardized and is used considerably in the testing of blast-furnace coke. A 50-pound sample of coke is dropped four times from a height of six feet upon a cast-iron or steel plate. The material is then screened to determine breakage.

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[8] **Navy Department Specifications, 7C2a, Coke, March 1, 1927.**

[9] **Standards, American Society for Testing Materials, 1927, Part II, pp. 574-578.**

Kinney and Perrott[10] investigated the test, using a wide variety of coke. They recommend that several tests be made and the results averaged. The average probable error of a single shatter-test determination is approximately two per cent. Shatter-test values for a number of different by-product and beehive cokes, based on the percentage remaining on a 2-inch screen, showed a range from 42 to 77 per cent. The Navy foundry-coke specifications state that the weight of coke remaining on a 2-inch screen after being subjected to the shatter test shall not be less than 70 per cent.

Tumbler or "Hardness" Test

The tumbler test has been used to some extent in testing furnace coke to determine the relative resistance of the coke to mechanical attrition in the blast furnace. A 25-pound sample of 3 to 2-inch coke is placed in a steel drum and the drum is usually revolved 1,400 times at a rate of 24 r. p. m. The exact procedure varies somewhat. The test is being standardized by the Coal and Coke Committee of the A. S. T. M. At the end of the test the amount of breakage is determined by screening over various screens; the so-called "hardness" factor is usually taken as the percentage of the original sample remaining on a ¼-inch screen. The breakage in the machine is apparently caused by both impact and abrasion. Perrott and Kinney tested seven different cokes by this method and found that the hardness values ranged from 70.6 to 77.5 per cent, a total range of only 7 in a value whose probable error of a single determination is approximately 1. Kinney and Perrott concluded that the test did not give any new or additional information on physical properties not shown by the ordinary shatter test. Some blast-furnace men consider the test to be of considerable value for testing metallurgical coke.

Cubic-foot Weight and Size Test

The Coal and Coke Committee of the A. S. T. M. has prepared methods of test for cubic-foot weight of coke and for sieve analysis of coke.[11] In determining the cubic-foot weight, a box 24 by 24 by 24 inches in inside dimension is used. The

[10] Kinney, S. P., and Perrott, G. St. J., *The Shatter and Tumbler Tests for Metallurgical Coke,* Ind. & Eng. Chem., Vol 14, 1922, pp. 926-941.
[11] Proceedings, A. S. T. M., Vol. 27, Part I, 1927, pp. 497-498, 500-501.

method of sieve analysis specifies square-mesh sieves with openings up to 4 inches. These tests should be of interest to foundrymen. The weight per cubic foot is dependent on the apparent specific gravity of the coke and on the size and shape of the coke pieces. The lighter the coke and the smaller the size, the more surface will be exposed per unit weight, which will affect the combustibility of the coke in the cupola. The property of reactivity, or combustibility of coke, is beyond the scope of this paper and has been discussed in many published papers. The difference of opinion as to this property is considerable; apparently reactivity is a function of coke which is little understood. Laboratory investigations of the reactions of different cokes with air and CO_2 have been made in this country and abroad. The reactivity with CO_2 varies with different cokes, and further work may show that this test is a measure of a property of coke of considerable importance.

The Division of Simplified Practice of the Department of Commerce recently requested the American Society for Testing Materials to consider the simplification of foundry-coke specifications. As a result, Committee D-5, on coal and coke, of the Society has agreed to form a sub-committee on foundry-coke specifications; this sub-committee is to be a joint committee with a committee on foundry-coke specifications of the American Foundrymen's Association. Any other desirable organizations will be asked to appoint representatives. The joint committee on foundry-coke specifications will include men familiar with foundry practice, methods of coke testing, and the preparation of specifications.

The matter was thoroughly discussed at a meeting of Committee D-5 held in Washington, D. C., on March 22, 1928. The committee realized that the present standard specifications for foundry coke are old and may require a good deal of revision. We have suitable methods of chemical analysis and have standardized and are standardizing various methods of physical testing. If we can successfully correlate the results of the various tests of physical properties of cokes with performance in the cupola, it seems logical to suppose that specifications covering simple requirements of chemical composition and physical properties can be put into specifications which will cover various grades of coke available for foundry use.

Casting Consciousness a Necessity*

By Arthur F. Jensen,† Chicago, Ill.

The past twenty-five years have marked an increase in the use of iron and steel products; since 1900 the output of pig iron measured on a per capita production basis, has advanced from 507 pounds per annum for each person in the United States during the first five-year period, to more than 620 pounds from 1920 to 1925. Steel casting production has grown from 11.2 pounds to 21.9 pounds annual production per capita and malleable castings show similar gains. During the past quarter century, the trend of gray iron castings production has been downward, as is indicated by the only measure available, viz., the production of foundry pig iron. During the first five years the per capita annual production of gray iron castings was 112 pounds, while during the closing five years, the yearly production was 97 pounds per person.

For certain purposes die castings, forgings and stampings are displacing castings and other industries are also reaching out for this business which previously went to the foundries. The change may be warranted in some instances by the economies effected, but it is more often attributable to the organized merchandising methods of the competing industries.

What Are Foundrymen Doing?

The malleable and steel casting industries are supplementing their excellent research activities with a publicity program emphasizing quality and use. But what is the gray iron industry doing to acquaint engineers, consumers and the public in general with the merits of gray iron castings, thereby discouraging unwarranted attack upon its product by venders of competing materials?

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*Presented on behalf of the Foundry Equipment Manufacturers' Association.

†Chairman Publicity Committee of the Foundry Equipment Manufacturers' Association and president Hanna Engineering Works.

At a recent meeting of perhaps our most prominent engineering organization a paper was presented stressing the superiority of the process advocated by its author over several other processes; the discussion which followed left no doubt in the minds of those in attendance of the merits of one of the methods attacked—the direct result of group activity. Not one word was uttered in defense of castings which have played so important a part in the safety and progress of humanity.

The foundry industry is confronted with the task of retaining the business it now enjoys, recovering lost outlets for its product and developing new markets. To improve the quality of its product is not enough—aggressive merchandising methods must be employed—user and producer must be brought together.

There are those who believe the public will seek the best, that it knows what it wants. B. C. Forbes, writing for the New York American, states "Just because an industry produces one of the necessaries of life it makes a fatal mistake when it assumes that people must step up and buy it without being invited or coaxed to do so," and E. St. Elmo Lewis tells us, "It is a fallacy that the public will demand over any great length of time what it is not reminded of."

The group which undertakes to solve this problem deserves the whole-hearted support of all interested in the prosperity of the casting industry. It will not be an easy task but apparently it must be solved if the foundry business is to progress.

Merchandising Program Needed

A definitely organized, competently directed and adequately financed merchandising and publicity program is demanded. It is a vital business problem with which we are confronted.

The program should be planned to embrace the following activities:

> Research to improve quality of product, using so far as possible the facilities of the American Foundrymen's Association, the Bureau of Standards and existing organizations. Co-operation in research activities is important to avoid duplication of effort;
>
> Research to maintain old markets and develop new uses and markets;

Keep the consumer and general public informed of the merits of castings, of new developments in the industry, as well as the extent to which castings are used in our more important engineering achievements;

Active participation in the meetings of all technical societies, both national and sectional, by the presentation of papers on methods, quality control and applications of castings in engineering constructions;

Encourage a "foundry consciousness" in our technical schools and colleges by a program of conferences, lectures, etc., in which foundrymen, existing organizations, supplymen and equipment manufacturers should co-operate. We must educate the engineer of tomorrow in the methods of the foundry industry and the services it is in position to render;

Compile and distribute statistics relative to the foundry industry's capacity, production, etc., enlisting the co-operation of the Department of Commerce of the United States;

Discourage the building of unnecessary additional foundry capacity, if the present survey by the Department of Commerce should make such procedure advisable; consider the liquidation of unprofitable foundries and the possible merging and strengthening of others;

Establish trade standards which will improve competitive conditions within the industry, as will also an interchange of production cost data;

Careful attention should be given to the selection and training of the sales staffs, with particular emphasis on the service castings will render rather than upon price per pound;

Organize regional groups to consider problems pertinent to production and distribution in the territories served.

Keep At It

Only by hard work and keeping everlastingly at it will it be possible to develop a "casting consciousness"; foundries and those interested in the foundry industry must survey the situation and

be prepared to meet conditions by drastic methods, if necessary; to merely await the return of "the good old times" is to invite disaster.

One foundryman very ably summed up the situation by saying, "it seems to be the fashion in the foundry industry, immediately someone suggests taking a pattern from the foundry, simply to quit arguing." More of the progressive spirit reflected in the following excerpt from an address by E. A. Custer, Jr., before the annual convention of the National Founders' Association, is desirable:

> "With our increasing knowledge of cast iron, and with the pearlitic iron as a base, and with its further development, a more ideal iron could not be imagined. An iron that, in its strength, in its ability to withstand torsion, fatigue, stresses and strains, is equivalent to malleable iron and in some cases equivalent to our steel, and has combined with these properties the rigidity of cast iron and, above all, can be produced with the same economy as cast iron. Were we to turn over and produce such a metal in this country, it does not take any great stretch of imagination to see what a tremendous volume of business could be brought back to the gray iron foundries."

"Casting Consciousness" an Inspiration

As we go about the task of creating a "casting consciousness" may we constantly be inspired by the following words of President Utley as expressed in his address before the Pittsburgh Foundrymen's Association:

> "As you and I work in the sand of the foundry, adding to the wealth of the world by creating those things which never existed before, we can take to ourselves the consolation that we have a definite place in the scheme of things not excelled by anyone else, and amid our trials and tribulations we can go calmly forward, serene in the certainty that for generations still unborn the world will be a better and happier place because we of the industry have lived and labored in it."

Science in the Foundry

By E. F. Hess,* Wadsworth, O.

A great deal has been written about science of technical control in the foundry, but there are certain points which the writer feels should be emphasized in order that a person not entirely familiar with the technique of such work may have a better appreciation of it.

As we have a great many persons interested in this phase of the industry who have not had special training along this line, and I might mention that some of these may be the owners, managers or superintendents of plants, it seems as though they would be more interested and give us better aid if they had a clearer view of what to expect when scientific control is contemplated in the foundry.

Of course, to those who are in this work all the time, this is old, but there are many who are coming to these meetings to find out the new ideas with a view of adopting, at least, the good ones.

Everyone must respect a foundryman and especially one of the old type foundrymen who has no scientific instrument to guide him and who still can turn out enough good castings to pay dividends. On the other hand, this same foundryman should (and I believe does) appreciate the help science can give him. He has enough worries, and everyone of the hazards that can be recorded and controlled so as to be made use of at a future time should be welcomed not only by the foundryman but all concerned.

It has only been in recent years that any amount of scientific work has been done along these lines—especially in the non-ferrous industry.

Laboratory Control

The first important scientific control work done in the foundry was that of making chemical analysis. After that we have

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temperature control of metal and various methods for control and conditioning sand.

Let us consider the above phases briefly; non-ferrous alloys could be analysed and this was done, but of the great amount which was melted not so much was made to specification, in fact, one might say that brass was brass and bronze was bronze and if it answered the purpose it was acceptable. The physical properties must be met and so long as these were satisfied all was well.

Perhaps through the War and through keener competition thereafter we became more alert to the saving made possible by close watch of our product and also by the fact that more material was being purchased under definite specifications.

A laboratory allows you to use brass ingot to its best advantage and the saving here alone pays for itself. First there is the saving in the price differential over new metal and there is also a saving effected by uniformity of the product as it goes through the machining, assembling and testing.

The scrap and chip accumulations from different mixtures can also be used to better advantage; and with the interchange of mixtures there is no need to carry large inventories.

As most of us are acquainted with the working of a laboratory we need not dwell very long upon this factor, but in passing I might mention that often analyses and results are expected too quickly. However, there are some short cuts which are good and give results accurate enough for routine work, although the choosing of the best methods to get accurate records should have exceedingly careful consideration. The one and all important thing to guard against is unreliable figures, as these are worse than none at all.

Temperature Control

The taking of temperatures of the metal with a pyrometer is one of the newer ideas being adopted. We talk of installing a pyrometer for this purpose and assume it is a simple matter and can be handled by anybody. This is all true but it takes more than this installation to give the desired results. Whoever takes the temperatures must be shown how it is done and it would be well to have the same operators on this job all the time, for, as mentioned in one of the papers last year, the open tip of a thermo

couple should be immersed about the same way each time to get consistent results, so it is plain that different operators could get temperatures that vary in the same pot of metal and this I have found to be true. This shows that the method adopted must be standard.

Different makes of instruments do not always check; so after we have accommodated our work to certain instruments, it would be well to be careful when making any changes. There is also the chance of the same instrument getting out of order and giving erroneous readings. To guard against this, each instrument must be checked quite often with a standard instrument and periodically the standard pyrometer and thermo couple should be sent back to the manufacturer or the Bureau of Standards to be checked. The chance taken here by dealing with unreliable figures is the same as previously mentioned.

Sand Control

Your sand can be regulated just as your metal and temperatures and this also has an important bearing upon the making of good castings. There are different forms of apparatus available, all of which tend to give similar results.

Various excellent papers have been written dealing with this subject, giving descriptions of the apparatus and results accomplished.

The cost of the testing equipment is not very high and it is surprising the good that can be accomplished through its use.

The installation of a complete sand handling unit, while ideal, would be quite expensive but this is not always necessary and the sand conditioning on a smaller scale can be done until its worth has been proven.

In this connection I might mention that taking one sand heap at a time and working it through a muller with additions of new sand will give very beneficial results. At this time the proper amount of water can also be added to bring moisture content to the desired percentage.

This sand is then taken back to the molding floor and screened through a vibrating riddle, after which it is ready for use.

One man working nights, can take care of enough sand to keep the heaps in a moderately sized brass foundry in good condition. Of course the moisture must be kept up as usual while the different heaps are being conditioned and also new sand added as found necessary.

Now granting that all the above equipment has been purchased your real job has just begun, for you have only prepared yourself to get concrete figures and have a record of what is happening, and a record must be kept of everything that is done.

Conclusion

After having procured these records there is another step which is fully as important, if not more so, and that is in the interpretation of the records. A job must be followed through from the beginning to its completion and the better it can be watched and notes made at different stages, and therefore more complete records kept, the more accurate and intelligent can you finally interpret these records and therefore get results which are favorable.

This paper has only been prepared in an attempt, as said in the beginning, to give those who attend these meetings a sort of general idea of what to expect, and that this apparatus aids science in a means toward an end.

Summary

Scientific methods afford an opportunity to make definite records.

Records allow definite deductions to be made.

Standard methods and reliable records tend to produce consistent results and the means by which these results may be duplicated at different intervals of time.

Interdependence of Operating and Sales Departments in the Success of a Foundry

By K. V. Wheeler,* Lebanon, Pa.

The subject of this paper is not one, the discussion of which may lead to conclusive proofs. A dozen writers could approach the topic in several different ways, using as many examples to illustrate the various points. Before we launch into our discussion of the subject, we would like to submit some definitions so that all of us will be starting from the same premise.

The word interdependence, according to Webster, is a "mutual dependence," in this case implying that the operating and sales departments of the steel foundry, drawing on each other for advice and help in their respective duties, each has distinct bearing on the success of their joint effort.

The operating department is that part of the organization which is responsible for the manufacture of the product, including purchasing, production, development, and research into methods.

The sales department is that part of the organization which fixes the selling price of the product, comes in direct contact with customers, is responsible for satisfactory service respecting deliveries, and insures a quality essential for the service required.

There is a third department in each organization which though not listed in the title of this paper, is quite essential to success. We refer to the statistical department, or a department designated by some other name, which is responsible for the accumulation and tabulation of data so essential to a correct understanding of the business as a whole, and of the individual jobs, the sum of which comprises the entire product.

It has been the writer's observation that success in the steel foundry is subject to various interpretations. We have known

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foundrymen who felt that success was measured by total sales value, by volume expressed in tonnage, or by the percentage of shop capacity utilized. Other foundrymen have considered success to result only from the development of methods enabling them to produce castings of a quality superior to those made by their competitors. In fact, we recall one foundry manager whose greatest ambition was to tackle those jobs which were giving trouble in other foundries. It was a source of keen enjoyment to him to produce such castings satisfactorily, often forgetting the cost of production and the commercial value of the product. Other foundrymen measure success by the degree of prestige or reputation they earn and enjoy in the industry, as pioneers in the development of its technique. Again there are certain foundrymen whose idea of successful business is to regularly secure work from their competitors without any regard for accepted business ethics, and whose keenest delight is the consummation of business deals which the orthodox business man might charitably term shrewd.

Our conception of success as applied to the steel foundry is a combination of net profits earned and the permanent growth or expansion of the company. The primary purpose of business is profit. Permanent profits are possible only if the conduct of the business is based on sound business policies, the prime requisites of which are satisfied customers, contented employees, and a reasonable margin between the cost and selling price of the product.

With these definitions, clarifying the meaning of the subject, we are able to start our discussion from a basis that prevents any misconception of terms used.

Let us now consider why, in a steel foundry, it is so essential that the operating and sales departments should always work together very closely. While the making of steel castings presents many problems quite similar to those confronting the manufacture of other products, it has certain inherent peculiarities, due to the material with which we work and the nature of the marketing problem. To illustrate this difference, let us compare it with the manufacture of motor cars.

Comparison Between Steel Foundry and Automotive Industry

The design of the car in all details is based on intensive study of service conditions. It is then built and thoroughly tested. If the results are satisfactory from the standpoint of performance, probable cost, and marketability, the attention of the operating department is then directed to the problem of volume production and cost reduction, the sales department to the intensive selling in universal markets, and the engineering department to new improvements.

The operating department, through repetitive production, can study the minutest details of every phase of operating, and the results of improvements are manifested in the cost, not on one car nor on one particular style of car, but on all the cars that may be manufactured.

The sales department's field is practically limitless, embracing the entire world, or we might say, that part of the population which can afford the luxury of a car, even to the extent of mortgaging earnings for years ahead.

Although through research and plant engineering we develop improved methods and reduced costs in the general production of steel castings, we do not, through engineering, research, and test, develop a steel casting or many steel castings of special design, and then pass them over to the sales department to sell. Steel castings are bought only after they have been specified by the engineers of other industries. Consequently the sales department is the beginning and the operating department the end, reversing the procedure of the automotive industry.

Peculiarities of Steel Casting Manufacture

Because of the peculiar characteristics of molten metal poured into sand molds, each new casting presents an engineering problem in itself. This is true regardless of the kind of metal employed. It is true in steel castings to a greater extent than it is with castings made from metals other than steel.

The greatest problem of the steel foundry is that of shrinkage and temperature. Cast steel, when cooling from molten to room temperatures, contracts within itself in both the liquid and solid state. Patterns are made oversize that the castings may

have proper dimensions. To take care of the contraction or shrinkage before and during solidification, provision must be made to compensate for the contraction of the metal in the casting. If the latter is of such design that this can not be accomplished by natural methods, such as the use of sink heads or risers directly over the member to be fed, artificial methods, such as the use of chills, must be employed to counteract this shrinkage, and synchronize, so far as possible, the cooling rates of the heavier and lighter sections. Excessive restriction will produce casting weaknesses, consequently the metal must be poured into molds which will not seriously resist the pressure of the contracting steel.

Each individual casting which varies from another casting, even to a small degree in one or more of its members, presents a distinct problem to satisfactorily counteract these shrinkage peculiarities of the metal, which must be solved by the careful study of the design and the thoughtful consideration of the metal's characteristics. There are certain fundamental principles in steel founding which are applicable to the making of all castings, but judgment, based on past experience with castings of similar shape and size, is equally essential to the solution of the problem.

The high temperature at which steel for castings is poured makes it quite difficult to obtain commercial materials of suitable refractoriness and stability to withstand fusion and erosion in the mold, and which do not cause undesirable chemical reactions in the metal of the casting. The size and design of castings materially affect these phenomena and must be carefully considered for each job.

The point we want to stress is that the making of any casting in steel is not solely a producing problem, but a combination of producing and engineering efforts, which vary with the type, size, and design. The stage of production is reached only after the sales department has acquired orders from those who have actual need of the castings.

As the automotive engineers have divergent views regarding materials, design, and construction, just so have steel foundry engineers developed different methods of satisfactorily making castings of the same design. In either case, it is a very wise or very impulsive man who declares that one is right and all others are wrong.

Pattern Equipment

This brings us up to the subject of correct pattern equipment, which is so essential to quality and cost in the making of steel castings. Pattern requirements will vary in different foundries, but that most suited to the foundry producing the castings should be supplied. How are we going to get the proper kind of pattern equipment excepting through the close co-operation of the operating and sales departments? The sales department knows what constitutes satisfactory pattern equipment for any particular job, only through information given it by its operating conferees. Obviously the operating department must secure the proper kind of pattern equipment through the sales department's contact with the customer. Here co-operation is indispensable.

Design

Let us now consider the question of design, which plays a most important part in securing castings which are sound in all members. Unfortunately the designing engineers in most industries using steel castings are unfamiliar with founding, particularly steel founding. Although we know that, primarily their aims are to design a product to meet required service conditions and lowest total manufacturing cost, it sometimes seems that some designers obtain their greatest enjoyment in conceiving veritable mazes of intersecting ribs and complicated bosses, which, from a foundry viewpoint, not only are impractical but in many cases impossible to satisfactorily produce in one sound integral piece of steel. However, it has been the writer's observation, as of many other foundrymen with whom we have come in contact, that the capable engineer not only tolerates but welcomes suggestions from the foundry, which will give greater assurance of soundness in castings, or will reduce the cost of their production.

The co-ordination of the ideas and principles of designing and founding can be brought about only through the intermediary of the foundry sales department. As in the case of patterns, the sales department gets its information from the operating department and transmits it to the designer. Again we see that close co-operation between operating and sales is indispensable.

In making these remarks, I am very conscious of the fact that many members of the foundry sales organizations are excep-

tionally competent and well versed in foundry technique, and in numerous instances can state the foundry's position without consultation with the operating department. However, in these fast changing times, progress and development are making great strides in the steel foundry just as in other lines of endeavor, and with new knowledge gained through research and development, the operating executives, obviously, are in the preferred position to say what is best from the manufacturing standpoint.

In the the discussion above, we have touched only those phases where the customer, by making concessions to the foundry, can render a service of mutual advantage. Let us now consider this from the opposite angle, viz., what the foundry can do to render better service to the consumer.

Delivery

Only through the sales department is the foundry advised as to the customer's requirements respecting deliveries and the desired characteristics of the castings. The average operating executive, if left to his own choice, naturally would make the castings on order, in the order of their intricacy or difficulty, starting with the easiest; and if sufficient new work of the more simple grades were forthcoming, the "stinkers" would lie on the pattern shelf indefinitely.

Only through the well regulated planning of the sales department through one of its branches familiar with the purchasers' requirements, will the castings be made in proper sequence to satisfy each customer. There must also be the full co-operation of the operating department in making the castings in order of their priority, regardless of the effort and time necessary to produce them satisfactorily. The close co-operation of operating and sales departments again is indispensable, for satisfied customers supply the only solid foundation for permanent business.

Special Requirements

Should the customer require castings of unusually good appearance, or from a special metal whose characteristics best suit the work required of that casting, the sales department must obtain all available facts to assist the operating department in

making the castings so that the desired results may be obtained. Co-operation alone brings about such a condition.

Cost Versus Selling Price

We will now discuss the relationship between cost and selling price. The difference between the two is, of course, vital to the life of any business. We recall one foundry of many years ago whose selling policy was to get the business at whatever price it could, and then put the order into the shop with the hope that the operating department could make the castings at a cost which would net a profit. When accepting business, practically no consideration was given to the character of the work, the intricacy of design, nor the probable high cost of certain jobs. Not only was there no co-operation between the operating and sales departments in that plant, but there was, in fact, very little contact. The patterns supplied were used as they came in or the foundry bore the expense burden to alter them. There was a woeful lack of information as to the nature of the service for which the castings were intended, and in many cases the orders for castings were taken at flat prices, disregarding the possibility that a major portion of the castings might be extremely high cost jobs.

As might be expected, the net results of that plant's operations were far from satisfactory, and it was constantly in financial difficulties. We are confident that a spirit of co-operation and mutual helpfulness between the operating and sales departments would have changed the whole complexion of this plant's outlook, and would have assured it a marked success, as it enjoyed a strategic position from the standpoint of marketing. In those days the policy of this plant was not peculiar to itself, but was in force in many foundries. Only those foundrymen who now follow a different procedure can lay claim to a fair degree of success at present being achieved.

We are thankful that the progressive foundry of today has departed from these old methods. Through the accumulation and tabulation of statistics, both on entire production and on specific jobs, the cost of producing each individual casting is known. Fairness to maker and user demands that each job should bear its own burden. If the castings are taken at a price lower than the cost, the foundry doing so is robbing itself of

legitimate profits, endangering its very existence if examples of this kind are repeated sufficiently.

It is not the purpose of this paper to discuss price fixing nor specifically to advocate the use of job costs. However, as the knowledge of costs, both general and specific, is fundamentally essential to successful merchandising, we can not refrain from mentioning sales price in so far as it may be affected by the co-operation of operating and sales departments.

The sales department, through its contacts and by the very nature of its work, is familiar with the market price of the product it sells. Many times this price is below the immediate cost of that product in its foundry. We will mention two solutions which may be applied with a reasonable chance of success in many instances.

As the sales department knows, or should know, the requirements of the customer, the personnel of his organization, and his appraisal of quality and service, it often is able to secure a selling price commensurate with the cost, providing the operating department produces a casting of excellent quality and renders exceptionally good delivery. By the very nature of the process all castings can not be perfect. Neither can all orders on the book be produced simultaneously. But if the sales deparment, co-operating closely with the operating department, keeps it advised when conditions are such as represented, and the operating department reciprocates by a little extraordinary effort, the castings and service may warrant the customer's placing the business at prices commensurate with service.

It may happen now and then that the sales department, knowing the customer's requirements, and learning that suitable castings may be purchased at a price which is lower than its own plant's cost, by giving this information to the operating department, may enable it to effect savings in short cuts, and changes which will lower that cost below the selling price obtainable. This may be accomplished in many ways, such as a knowledge of future orders of the same part justifying additional pattern equipment or a change of design suggested by the operating department which naturally reduces the cost of manufacture, or, by a very careful study of the methods employed, enabling the operating man to make changes which will effect the required

saving. We have known of steel foundries actually constructing and starting production on as many as 175 patterns in one month. Add to this several times that number of items from patterns previously made. You will appreciate that this intensive study of each job is not possible without an organization that would, in some industries, be regarded as out of all proportion to the sales value of the product. With the knowledge the sales department should have, selective jobs can often be chosen where such changes are practical and profitable. Again we see that close co-operation between operating and sales departments is quite indispensable to the success of a steel foundry.

We know that the points we have tried to make do not embrace all of the arguments in favor of close co-operation between the departments of a foundry organization. What we have said, however, together with what we have learned but not tediously related in this paper, convinces us, as we believe it would any student of the problem, that ignorance is responsible for a large part of the poor selling so common to our industry. If the thoughts expressed stimulate at least a little reflection and discussion which will help some steel foundry in solving an ever-present problem, we will feel well paid for our effort to promote what we regard as constructive policies that aid all intelligent producers and consumers.

In the final analysis, the manufacturing and merchandising of steel castings present a problem requiring technique, tact, ability, and above all, good common sense, which are most profitably applied in an organization made up of individuals who know each other's problems and who work together closely and harmoniously. "The Interdependence of Operating and Sales Departments in the Success of a Foundry," is nothing more than the exemplification of the well known slogan, which has carried to success many an enterprise, commercial, civic, and national: "In union there is strength."

An Incentive Bonus Plan for Molders Based on Scrap Control

By R. J. Teetor,* Cadillac, Mich.

The wage incentive plans with which we are familiar have as their basis speeding up production and thereby lowering the cost per unit from a labor and capital investment standpoint. These plans are effective, and some of them show excellent results.

The plan discussed here resulted from the consolidation and modification of two plans, each of which showed some value, but also some disadvantages. The first plan employed aimed at increased production only, without any consideration being given to scrap percentage. It operated as follows:

Piece rate for the job was established.

A normal rate which an average molder should be expected to earn was established at 50 cents per hour.

The bonus consisted of the addition of 100 per cent to any earnings in excess of the normal expectancy of 50 cents per hour.

Example

Molder earned an average for ½ month	58 cents per hour
Normal expectancy rate	50 cents per hour
Difference	8 cents per hour
We added bonus of	8 cents
Making total pay	66 cents per hour

It was necessary under this plan for the molder to work consistently each day in order to earn a bonus. He could not profitably work at a high rate for a day or two, earning an excessive bonus, and then let down for a period to rest up, because his hourly earnings were computed for the entire half month at full time daily. The plan, however, put no premium on percentage of good castings, and had the effect of speeding up the

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making of molds with a lowering of the percentage good. The molder worked faster, but not more carefully, in the hope that he would get out enough good work to earn a bonus. The plan was weak also because the loss of a day or two on account of absence deprived the molder of any bonus whatsoever.

The second plan evolved jumped to the other extreme, and offered a bonus based upon good percentage average for the half month without regard to total amount of production or regularity of attendance. The bonus took the form of a percentage of total pay for the half month, based upon percentage of castings good. Under 85 per cent good, no bonus was earned; 85 per cent good entitled the molder to 10 per cent of pay for his bonus; 86 per cent allowed him 12 per cent, and on up to 100 per cent good, which would entitle him to 48 per cent of pay for his bonus.

This plan was weak because the incentive for larger production was overshadowed by the incentive for a high percentage of good castings. It had the effect of reducing the scrap per cent to a fairly low figure; but apparently made the molder ultra-conservative, and slowed him down to a too low production rate.

After a few months trial of this second plan we worked out a schedule which has been in effect during the last two and one half years, and which has been found practicable, embodying the good points of the earlier systems, and eliminating the disadvantages. This plan is as given in the following discussion:

Regular Pay

Each pattern is given a piece rate. For each pattern is established the number of molds to be produced daily as a normal day's work for an average or fairly good molder. If the molder exceeds this normal day's work for a sustained period of one half month, he receives payment for his excess above the normal average day's work at double the regular piece work rate. The molder is notified of the piece rate and the number of molds he must produce daily to be entitled to any double pay, on his job card, and these figures are never revised downward unless a change in pattern equipment justifies such change. They are

sometimes made more liberal when we are convinced the piece rate has been established too low, or the doubling figure so high that the average man cannot ordinarily participate in the double rate.

Example

Rate per mold	5 cents
Normal day's production	100 molds
Normal day's pay	$5.00
Molder actually produces	120 molds
Normal day's production	100 molds
Molds produced above normal expectancy	20
20 molds at double rate, or 10 cents	$2.00
Molder's pay is therefore	$7.00

Bonus

The bonus is based purely upon percentage of good castings, and regularity of attendance. The schedule is given in Table 1.

Table 1

Percentage of Good Castings Produced	Bonus in Per Cent of Regular Pay
Up to 90	No bonus
90 to 91	10
91 to 92	12
92 to 93	14
93 to 94	16
94 to 95	18
95 to 96	20
96 to 97	22
97 to 98	24
98 to 99	26
99 to 100	28

Only molders working full time during the pay period will receive full bonus. Men absent ½ day will receive ⅔ of bonus, men absent 1 day receive ⅓ of bonus, men absent 1½ days receive no bonus.

The bonus is paid with a separate check. The regular pay check goes presumably to the wife for living expenses. The molder can, with a fairly clear conscience, put the bonus check in his own pocket for his personal use.

Employer's liability insurance premiums are calculated upon the regular pay only, and not upon the bonus. The latter is not paid for increased production, but for better quality of product.

Molders' pay and bonus are given publicity. Daily reports are posted on bulletin board showing molders' percentage, good and bad. Semi-monthly sheets are posted showing:

Hours worked by each molder,
Average hourly rate of pay for each molder,
Total pay for each molder,
Bonus hourly addition for each molder,
Total bonus for each molder.

It has been found that this publicity has the effect of stimulating less experienced molders to put forth greater effort, and inducing good spirited rivalry among the more experienced men.

Our experience shows that the average extra pay, or double pay, is 8 per cent in excess of the regular piece rate pay, and the average bonus is 10 per cent, making a total of 18 per cent. However, as molders' earnings comprise but 11 per cent of total cost, this increase of 18 per cent due to bonus and double pay represents an actual addition to overall cost of but 2 per cent.

Against this 2 per cent apparent increase in cost are savings which we have found to be approximately ten times as great. These savings result from:

Reduction in remelt,
Reduction in hard cleaning cost,
Reduction in trimming and inspection cost,
Reduction in grinding cost,
Reduction in anneal cost,
Reduction in soft cleaning cost,
Reduction in soft inspection cost,
Increase in production per molder,

which reduces all overhead fixed charges per ton of good castings produced. The plan has operated to greatly reduce turnover, of course.

Industrial engineers tell us our method is wrong because it actually increases the molding price per piece, instead of decreasing it. It does do this; but while doing it, it has been found to bring about the indirect savings mentioned before, which overbalance the increased molding cost about ten to one.

We believe, too, that the trend of compensation for molders and all other labor, whether skilled or unskilled, is definitely set in the direction of participation in as large and as accurately computed a share as possible of such savings as can be directly

traced to their conscientious efforts. Furthermore, we are in thorough accord with this trend, and think it an economically sound policy to follow it.

WRITTEN DISCUSSION

R. E. Belt: The bonus plan presented by Mr. Teetor is in effect an increased rate of compensation to the molder for, first, an increased production, and secondly, a decreased scrap loss.

There is no doubt in my mind as to the advantage of his company of the second feature of the bonus plan, namely, a sliding scale bonus based on the percentage of good castings. There are direct savings accruing to the foundryman as a result of a decreased scrap loss and an increased percentage of good production. Their costs of production undoubtedly are decreased through the payment to their molders of the scrap bonus.

As to the first feature of their bonus plan, namely, a straight bonus as an incentive for an increased production, there is real doubt in my opinion if the employer is benefited thereby to any considerable extent, if at all. I would expect to find that part of their bonus plan to increase their cost of production instead of to decrease it. When the molder is paid a piece rate for his good production only, as is the custom in the malleable iron industry, and when the rate per mold is increased through the putting up of a larger number of good molds, the molding labor cost per ton is unquestionably increased, and likely without any corresponding decrease in other operating costs. If the increased production per molder per day, through the bonus plan, resulted in an increased plant output, then there would be compensating benefits to the employer through a reduction in fixed charges and general overhead. Without an increase in output from the plant as a whole, and when a plant throughout the year has idle units of molding floor space, as practically all companies have had throughout the period in which the plan described is stated to have been in effect, the payment of a molder's bonus as an incentive for increased production would seem to be more advantageous to the employee than to the employer.

Of the two factors of the bonus plan, the incentive for keeping the scrap loss to the minimum is in my opinion of far more importance than is the incentive for increased production which results in an increased molding labor cost. No great amount of weight can be given to an increase in the average production per molder per day if the increase results in a higher molding labor cost, particularly if the increase in production has the effect of reducing the number of molders required and not of increasing the aggregate tonnage of the plant.

What Does the Buyer Expect for His Money?

By J. A. Marks,* Detroit, Michigan

There is a great deal of discussion going on about ruinous competition, profitless prosperity, buyer's market and so on, that indicates that those who produce, manufacture or sell, believe that the buyer is getting or expects to get too much for his money. When we consider that, no matter what conditions are, the seller never thinks he is giving too little for the buyer's money, it is rather easy to understand why buyers generally do not take this situation seriously. It should be taken seriously, however, and should be frankly and freely discussed between all who are interested in any phase of this great industrial era in which we now live, whether they are buyers or sellers.

Everyone in business realizes that the present is a period of keen competition. The condition existing today is an aftermath of the one that existed a few years ago. This is all well understood by business men but it will do no harm to recite the reasons for the problems with which we now have to contend. We are in this period of keen competition because there are more goods available, or more facilities for producing goods, than are needed to supply the demand of those who want to or can buy.

Fourteen years ago the great war started and immediately there was created a demand for supplies that did not exist before. At the same time the countries at war in Europe had their own ability to produce hampered by the loss of the men who took on the occupation of soldiers. This country was called upon for food, coal, clothing, automobiles, arms and ammunition which it had never been called upon before to supply. Ten years ago, after the first stimulation of our industrial structure by the warring European countries, we ourselves entered the

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war. Immediately industry in this country was called upon for supplies for our own army and navy. This carried on to the end of the struggle. The condition of false industrial stimulation continued for several years, making up for what had been neglected during the war. There were urgent needs of our civilian population to be filled. Buildings had to be constructed, railroads to be rehabilitated, roads to be built, automobiles and farming machinery to be made, and so on. So for a while we thought we needed all the plants that had been constructed, and machinery that had been provided, and coal, iron, and food that we had been producing in this period during which we made goods to be destroyed by war.

We must bear in mind, also, that England, France, Italy and particularly Germany also expanded their facilities to support their armies and navies and countries during a condition of emergency, and that they are therefore in a new position with respect to the competition to supply the world with peace-time needs.

When the neglected demand had been filled we found ourselves producing more than our country and the rest of the world needed and could absorb. We have been struggling ever since to adjust ourselves to this condition and will probably struggle several years more. The history of the periods following great wars has always been the same.

And so we have this so-called period of profitless prosperity. We have to meet this situation and we might as well face it with our minds made up to solve the problem as it is before us.

Studying the facts we have and the industrial history following other wars indicate that the adjustment to supply the world with what it can consume rests on the working out of several factors.

Nothing short of another great war would immediately return industry to the point where a demand would be created for all the producing capacity which we now have. We all hope that the solution to our industrial problem does not come this way. If the demand for peace-time goods could be stimulated by greater production per man employed and per dollar invested we would have the ideal solution. The more labor and capital produces the more it can consume. A workman employed effi-

ciently and continuously earns money with which he buys not only the food he needs and wants but more clothing, radios, and automobiles, and has more money to spend for luxuries and entertainment. At the same time capital is employed more continuously and profitably and its earnings are similarly available.

Labor and capital can be more efficiently employed. Those owning property in the way of land, buildings, factories, or machinery and having money to be used in trade or business never object to its more intensive or continuous employment. Labor being human is always afraid that it is going to have to give more of itself and so is always reluctant to accept any suggestion that involves greater effort. On the other hand, any individual is ready and willing to apply himself intensively and continuously for what he considers suitable reward, as long as the effort lies within his physical capacity. The criticism for lack of efficiency does not reflect on labor itself but on those who employ and direct labor. It is human nature to do a job efficiently. A man will always find the easiest and best way to do his work if given free rein to do so. We often see this exemplified in those industrial organizations in which wage incentives are employed, particularly if the employees are given the full advantage of their ingenuity.

Capital and labor make a great team if they are co-ordinated and work together. Capital's part is to furnish the facilities with which labor can work efficiently. At the same time, capital must not expect to take the whole advantage of the increased efficiency. If it does not share it with labor the full effect is lost. And it is to capital's double advantage to be fair and even generous with labor, because the more labor earns the more it has to spend and the more it can then contribute to the general prosperity of the community and country.

There is another factor which will help in the working out of the present situation. As time goes on and labor and capital work together for increased efficiency, new methods and new plant facilities are developed. This makes the old methods obsolete and unusable in competition with the new. As the plants consisting of machinery and buildings built to suit industry's needs ten years ago become unable to compete with the newer ones, they go out, and thereby eliminate the high cost producing

factors in the problem. At the same time the producing capacity is reduced and the level is nearer reached in which the supply of goods is more nearly equal to the demand. At the same time the cost of goods is reduced.

The balance between supply and demand is a very fine one. Consider an empty barrel being filled with water from a hose running a full stream. As long as the barrel is not full it will take all the water the hose will deliver, but as soon as the water reaches the top of the barrel it is full all at once. If the hose stream is shut off and just a pail full of water taken out of the barrel, the full hose stream can be again emptied into the barrel until it is again full, but when the barrel is full it will not take another drop without running over. The condition of supply and demand is the same way. As long as the supply is less than demand and vice versa, the situation is acute. Just the instant that the supply equals the demand the barrel is full and there is room for no more. We do not know how much the supply of any one commodity exceeds the demand, but just the minute the balance becomes equalized then this condition of keen competition will change.

Many managers are taking business today into their plants with the expectation of making very little if any profit just to keep their plants and organizations busy, and thereby prevent losses through overhead charges which go on any way whether their plants are busy or not. These managers are waiting for the barrel to get just a little bit empty.

On the other hand, there are others in the same lines of business who are taking orders at the same prices and are making a profit, because they have developed means of greater efficiency in their plants. And this, perhaps, points the best way out of the so-called profitless prosperity problem.

One of the conditions which go hand in hand with overstimulated prosperity is laxness in management. With plenty of business at profitable prices there is a tendency not to improve methods. The close analysis of methods for the time being is not necessary. Increased efficiency of labor is neglected. Salaries and wages are increased without obtaining increased results. A few years ago many managers were demanding men to help manage and direct their businesses which the managers felt was

taking too much out of themselves physically. The managers believed they needed more recreation—more time for golf. There was a demand for high-grade capable men to whom industry was willing to pay large salaries. This was all right enough while those men were needed and industry could afford to pay them. Too many organizations are still trying to keep these men when the need for them has passed, in the hope, generally, that the conditions of their need will come again.

There are many concerns operating profitably today on low prices because they have trimmed extravagancies to the bone. They have thrown out obsolete equipment. They have eliminated inefficient labor. They have studied their methods and cut out all except those which are absolutely needed for efficient operation. They have given their labor opportunity and encouragement for economical and increased production per man. They have eliminated every item of extravagance in management.

There are other concerns which have not done all this. Some have done part of it but not enough to get themselves in a position to make a profit on their low priced business.

Many producers or suppliers are criticizing the buyers for what they call "hand-to-mouth buying" methods and attribute some of the present, to them, unsatisfactory situations to this practice. They argue that they are unable to produce economically without long contracts or large orders. It is true, of course, that continuous production is more economical than intermittent. On the other hand, there is nothing to be gained by continuous operation if it is to be followed by a period of complete cessation on account of over-production. The critics of the buying for current consumption in vogue today also argue that it subjects their trade to excessive and frequent competition because the buyers are continuously in the market. We must not forget that prices will be established by the relation between supply and demand in the long run and that frequency of buying has nothing to do with it.

The practice of buying for current consumption is economically sound because it keeps capital more profitably employed. When large orders are placed for materials to be manufactured the recipient goes ahead confidently that the materials will be used at the rate specified in the order, and that he will receive

another order before the first one is completed. He invests his capital in raw material, employs labor, and builds up his organization. If the materials are not used by the buyer as rapidly as anticipated somebody's capital is forced to lie idle, invested in that unused material, until conditions change and it is used.

The policy of carefully studying and estimating needs over a relatively short period in the future is growing. The practice of buying for current consumption and immediately working up materials into usable and salable products is becoming more and more current in industry. The automobile manufacturers were the leaders in developing this practice. A great amount of the material used in the manufacture of automobiles is received, manufactured, and sold within a few days so that the interest charges on the value of the goods are kept at a minimum.

This is efficient employment of capital and is just as important as efficient employment of labor.

Another factor contributing to more efficient use of capital is the speed of transportation. It is safe to say that the time during which goods are in the hands of transportation companies is less than half which that time was ten years ago.

It may seem that the point of this discussion on what the buyer expects for his money has been lost, but what has been said after all has an important bearing on the subject. The buyer will get for his money just what economic conditions determine he shall have. Those who are in the position of sellers can put their houses in order to meet the economic condition of keen competition by studying the needs of the situation. In order to give the buyer what he is going to get for his money and make a profit is the problem of the seller. There are certain essentials to his success along this line which can be stated briefly. It is necessary in periods of keen competition for the successful and profitable business to buy wisely, limiting its commitments to economical quantities that will permit of the most active employment of capital and the taking of the full advantage of competition.

The successful manager will study his methods of manufacture, equipping with machinery and other plant facilities for highest efficiency, bearing in mind that there is a balance to be obtained between investment in plant and inventory, so that his

investment in plant will not reach the point where the reduction in cost thereby is not more than offset by the increased interest and depreciation charges.

Labor must be employed efficiently. The task for each man and woman must be accurately determined, so that each may in turn contribute his or her utmost share well within the limit of their capacity. At the same time labor must be fairly and suitably rewarded or this condition will not remain permanent.

The so-called overhead or burden must be carefully controlled, particularly that which has to do with non-productive labor. Those whose work does not appear directly in the product contribute just as importantly to the cost. Non-productive or indirect labor should be just as carefully studied and apportioned as the direct. Particularly must the work of higher salaried people be watched to make sure that each is contributing in a constructive manner to the end that the most economical result is obtained.

The cost of distribution, including sales and advertising, must be carefully considered. The customer who is already sold looks askance at further sales efforts because he feels that the portion of his dollar that the supplier spends for this purpose is wasted so far as he is concerned.

Finally, then, the careful and intelligent buyer under any condition of competition is going to get all that he can for his money. In periods of competition like that in which sellers are now placed, it is the seller who determines whether he is going to give the buyer the most for his money or someone else. In order to meet this competition and stay in the game, it is necessary for the managers of each business to see that they themselves are buying wisely, manufacturing efficiently, using economical methods and machinery, holding plant and inventory investment to a minimum, getting the most out of labor, selecting their supervisory people and paying them wisely, and looking to their distribution costs.

Competition is not ruinous. We are not in a period of profitless prosperity. There is nothing to this buyer's market bugaboo. All that is necessary is living and working in the present and planning for the future, to make business healthy, happy and constructive.

The Need for Research in the Foundry

By E. E. Griest,* Chicago, Ill.

In September, 1926, at the banquet of the thirtieth annual meeting, C. F. Kettering, vice-president, General Motors Corporation, delivered a splendid address on "Research and Progress." I was very much impressed with the thoughts in that splendid paper. Perhaps all of you were likewise impressed, as I know many others were. Mr. Kettering's paper was devoted to the foundry industry generally, while my remarks will be confined to the malleable division of the foundry industry. The same general principles apply to all branches of the foundry industry, yet we, in the malleable division think (perhaps know), that we have troubles and problems relating to the production of castings that are more difficult to conquer, than those in any other division of this great industry.

It seems to me that Mr. Kettering's subject had the principal words in the answer to the query—"The need for research in the foundry?" Is it not fair to say that *research* means *progress?* We may amplify this by saying we cannot have progress in the malleable foundry industry without research work and lots of it. It is true we have had it in the past, but we must have much more of it in the future, if we are to maintain our standing with the other groups in the foundry industry.

All of us appreciate the importance and value of research work, but do we not all, too frequently, think and say that research work is all right in chemistry and medicine, but common sense is what is needed in the foundry. We do need common sense, but we also need research work. I like to think of foundry executives and foremen, and sub-foremen as researchers; not just supervisors. If we could just drive home to every sub-foreman, foreman, and superintendent that he must be a *researcher,* as well as a supervisor, don't you think our troubles would be materially reduced?

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Since research work is so frequently associated with abstract and scientific problems, it sometimes seems to me to be unfortunate that there is not some other word that could be used that would convey the same thought, but would not give the average foundry man the feeling that he cannot conduct research work without an extensive laboratory, elaborate scientific equipment, and highly trained technical men. The foundry needs laboratories and scientific equipment, and technical men, but these are not *necessary* for research work. Mr. Kettering said, "I would sooner have one good, thinking man in an attic, than all the big laboratories and equipment in the world. After all, all that equipment is for, is to get into some fellow's head what the problem is, for the solution comes out of the *head, not* out of the *laboratory.*" There is a gem of a thought to carry home to our foundry men.

Now just what is research. There are several definitions, but the one I prefer is in the standard dictionary:

> "Diligent protracted investigation, especially for the purpose of adding to human knowledge."

All research work need not be protracted or unusually extended, but all research work should be *diligently prosecuted,* and if necessary to accomplish the purpose, it should be protracted. Any one of you researchers can cite splendid examples of research work that were brought to conclusion by a few hours intelligent consideration, while others have been studied for years, and the solution is not yet in sight.

We generally associate research work with that of the great inventors, scientists and doctors. We are not surprised to learn that a scientist devotes his entire life's work to the study of some disease that has baffled the best minds of the age. Where the welfare of mankind is at stake, there may be a dozen or more scientists in as many countries devoting their entire time and energy to the solution of some problem, and it is not unusual for two scientists of far separated countries to divulge discoveries almost simultaneously, that are the result of many years of intensive research work.

Only a short time ago we read of telephone communication being effected between the United States and England. It was interesting as an achievement, but few thought of this as a result

of almost fifty years of intensive research work of the best minds of America and Europe. Research work has made possible the telegraph, telephone, radio, steam engine, electric light, automobile, higher quality malleable iron castings, and, as a matter of fact, every agency that has made for progress in civilization.

It is quite apparent that research work is necessary for progress in civilization. Scientists tell us that man existed five hundred thousand years ago. Progress must have been mighty slow, and research work little practiced 500,000 years ago, because it does seem that much more progress has been made during the last 100 years, than was made during the previous 499,900 years. And, is this not explainable by the theory that research work merely is the outgrowth of education, enlightenment and necessity? For 499,900 years, people were content to travel by boat, or on animals, or walk for great distances, and had to be satisfied with progress at the rate of a few miles per day.

A little over 400 years ago, it took Columbus 76 days, or at the rate of two miles per hour, to sail across the Atlantic ocean. A seaplane, making almost the same mileage, took less than 30 hours, or 1/63rd the time that was required by Columbus. In the last 100 years, research work has developed the present high speed efficient transportation systems from mere lines of timbers, over which were hauled wagons by puffy little steam engines, which could operate short distances at the extraordinary high speed of 20 miles per hour. In 1900, automobiles were practically unknown. Now we have more than 24,000,000, and authorities say 4,000,000 will be built this year. Here is a splendid example of marvelous progress by research work. The important automobile companies being large organizations, have special departments made up of researchers delving into every phase and kind of production and materials. That immense proving ground of the General Motors Corporation at Pontiac, is merely an immense outdoor research laboratory. When industries progress as rapidly as has the automobile industry, they derive benefits from researchers of other organizations, and thus get the benefit of years of patient investigation.

The malleable foundries have kept pace, in a general way, with the fast pace set by the railroad, automotive and other indus-

tries. We are making castings today of designs and to tolerances and in amounts that would have been considered impossible a few years ago. Our researchers have co-operated with the researchers of other industries and assisted the other industries in making the spectacular advances we have all been so proud of.

The Government maintains a large research organization in the Bureau of Standards at Washington. This organization cooperates with industrial organizations, and private individuals where the public interest is involved. With more than 24,000,000 automobiles in service, certainly the public interest is involved in any research that will effect economies of operation. As outstanding examples of spectacular results from research work, it is interesting to know that a few years ago, the Bureau of Standards conducted researches into the quality of automobile brake lining. They found some brake lining that gave 20 times the life of other brake lining that was being used. As a result of this research work, the average life of brake lining was increased seven times, which, in the year of 1925, effected a saving to automobile owners of $40,000,000. They also conducted researches into the relative merit of cord and fabric tires, and found that a car running at 25 miles per hour, saved one horsepower with cord tires over fabric tires. The saving in gasoline expense by substituting cord for fabric tires resulted in a reduction of $40,000,000 in gasoline cost.

Few, if any, engineers or buyers will ask us to increase the physical characteristics of our product *seven* times or will ask us to produce it in 1/63rd the time now required. There are engineers and buyers who realize, as we do, that a malleable iron casting is a splendid product when it has ultimate strength of from 50,000 to 55,000 pounds per square inch and elongation from 10 to 15 per cent and when it has strength, as it frequently does, from 55,000 to 60,000 pounds per square inch and enlongation from 20 to 30 per cent, it is truly a marvelous product. We know these are common standards of today. Our problem is to supply *sound* castings with these characteristics at all times. Because some of us have not done so is the reason for prejudices and occasional expressed dissatisfaction by some buyers and engineers. In my opinion the reason we have had these failures is because we have not practiced researching as we should have.

We are living in an age of speed—industrial speed. The year 1927 was unquestionably the fastest year of the fastest decade the world has ever known. And, 1928 will be faster—for those who survive. And it is those concerns which recognize the importance and value of research work that will keep up with this tremendous speed. Industry is not merely buildings and machinery, and just men, but men with progressive ideas—researchers. That is what the successful 1928 organization must have.

I have heard, as perhaps all of you have, that foundries generally, and malleable iron foundries in particular, have been less progressive than other branches of industry. It has been said that the same methods of melting, of molding, of annealing and finishing are in use today as were in use fifty years ago. Now, as a matter of fact, such statements are incorrect, at least they are incorrect as to some foundries. Good progress has been made in the art of making malleable castings. There is much yet to be done. There are still prejudices to be overcome. There is now, and perhaps always will be, a place in industry for malleable castings. There are times when we think the demand is decreasing. Is not that our fault? May that not be attributed to lack of research work on the part of our production and sales departments?

There is a place in industry for all kinds of castings, bronze, brass, aluminum, gray iron, steel, and malleable. There will always be some over-lapping of fields, and there will always be keen competition between certain branches—one branch trying to secure the business of another branch. We cannot afford to stand idly by and watch our business slip away. We must be the aggressors.

With intelligent research work on the part of individual foundrymen, we have the opportunity of meeting present day conditions, and holding our own place in the foundry industry. The Malleable Iron Research Institute has done splendid work, and unquestionably has done more for our industry than any other single agency, yet it cannot solve all the problems of the individual foundry. It is doing work as a disinterested party that no individual foundry could do. While it gives assistance on any problem to any member foundry, yet it cannot *make good*

castings. It is fulfilling it's mission splendidly in a broad way—the only way such an organization can function. We must not expect such an organization as that, or as the A. F. A., to solve all our problems. We need such general research organizations to supplement the work of our individual researchers, and to handle problems that are too general, or may be too technical for the average foundry. The responsibility of satisfying a customer and maintaining a proper standing for malleable castings is directly that of the individual foundry, and it belongs to no one else.

Perhaps a few examples of simple research work that have come to my attention will tend to emphasize the point I am trying to make.

Practical Research Results

A few years ago, we received an order for large castings from an important railroad. The price obtained at that time permitted the production of these castings by usual methods with a small profit. Keen competition among the malleable foundries, as well as from steel foundries, and everyone will admit that we have had this, forced the price down to a point where our manufacturing cost was above the price we could obtain. Delivery was also an important consideration. The customer thought it necessary to place orders with a number of foundries, in order to be assured of sufficient castings to take care of his requirements. By usual methods, a good molder could produce about 100 of these castings per week. Such production did not begin to take care of the customer's requirements. Our researchers got busy and by conscientious and intelligent effort, and the better utilization of some new equipment, brought the production of these castings up to 200 per day, instead of 100 per week, and with this increased production reduced the cost about 40 per cent, which permitted the sale of these castings at competitive prices, gave us a fair profit, and may have held this business in the malleable branch.

A few years ago, our manufacturing order department figured that one expert molder had to be assigned to a certain pattern to be assured of a production of 500 castings per week. Since these castings were used in large quantities, the foundries had difficulty in securing a sufficient number of competent mold-

ers to run these patterns. Today, instead of getting 300 to 500 castings per molder per week, we are now getting 1100 per week from unskilled, but specially trained men. In other words, where we were formerly obliged to have from six to ten highly skilled molders to get 3000 castings per week, we now get this production with three men, none of whom need be specially skilled in molding. There is another advantage in such a procedure, other than the mere increase of production per man, and that is, these three men work together and co-operate to a maximum extent, and produce as many castings in one day as the highly skilled molder formerly produced in an entire week. Now, when an order comes in for a large number of castings, the routine of the foundry need not be upset by changing jobs with a dozen molders, but because we can be assured of this definite production from these three men, a large order goes through the foundry without any disruption of regular routine. A few years ago, when this high production plan was being inaugurated, it was generally thought that we would be obliged to accept higher foundry losses, because of this greatly increased production. During the past year, our researchers proved the fallacy of this assumption, and brought the foundry loss down 50 per cent, covering several months' operations, below what was ever obtained by the old methods.

While visiting a foundry sometime ago, the superintendent spoke to the foundry foreman about the small production they were getting from a particular pattern. It developed that the delay was due to the failure of the foundry to get proper cores in sufficient quantities. He suggested another core box. Since this core box was rather expensive, and would require several days to make, the superintendent visited the core room to ascertain if the required production could not be secured from the one core box, even though it might be necessary to work some overtime. This investigation developed that the core room was actually making a sufficient number of cores. Further investigation and researching brought out the surprising fact that 30 per cent of the cores that were made, were being wasted in one way or another. The foremen from the foundry, core room, and pattern shop investigated this problem, cut down the core loss from 30 to 3 per cent, reduced the foundry loss from 12 to 4 per cent,

increased production materially, and found it unnecessary to make the additional core box. While this is a small detailed job, yet we all know that it is the total of all of these small jobs that runs up the total foundry loss, and increases the labor cost.

In another instance the foundry was having an exceedingly high foundry loss on a high production job that just had to be run. The researchers seemed to be unable to get their fingers on the vital point. A suggestion was made that the trouble might be traced to faulty cores, although at the time it was not thought that this was the cause. It had been suspected that the trouble was due entirely to faulty foundry practice. Unfortunately, the core room foreman had not been drawn into this research work before that time. He immediately started an investigation, and much to everyone's surprise, the trouble was located in the slight shifting of a small section of the core. After the castings had been made, this fault was not apparent. The trouble was immediately corrected, and the loss was immediately reduced to normal. This illustrates not only the value of research work, but it emphasizes the importance of co-operation.

In planning some new patterns for high production machines, we found that a single pattern would cost about $700.00. By research work and full co-operation between the foundry foreman, pattern shop foreman, and our engineering department, we were able to make a combination pattern for slightly more than $700.00 that took the place of three $700.00 patterns. We not only saved a matter of $1400.00, but we saved the expense of handling these extra patterns, storing them, and changing them. As a matter of fact, the combination patterns can be changed from one style to the other in one-fourth the time, than would be required to change the patterns if they were independent. I consider this a very excellent example of intelligent research and co-operative work.

Some months ago, an order was secured for relatively large castings from an automobile accessory concern. The castings were quite large, and of intricate design. A good molder would turn out 60 or 70 castings per day. By intelligent research work, it was found that this job could be placed on the proper kind of machine which we had, and 600 castings could be produced per day with three men. The customer was unwilling to give any single foundry all of this business, as he had had experiences

with other foundries which ran the patterns with skilled molders that had caused interference with his production schedule. When he was told that we wanted all of the business, and that we could assure him shipments at the rate of 500 per day from one pattern, he was skeptical. He went to the trouble of sending an inspector to our plant, and after this representative had watched the operation of the machines and inspected the castings, and saw that they were much truer than any castings they had ever received heretofore, he reported to his superior that in his opinion, they could not afford to purchase the castings from any other concern. Here is an example of research work that not only permitted the production of more satisfactory castings, but enabled us to quadruple our business with that concern.

All of the research work should not be confined to the production department, although I think it is fair to say that there is greater need for research work in the production department, than there is in the sales department; nevertheless, the sales department can accomplish much by following the policy of research work that should be established in every production department. As an example of this, one of our foundries was securing orders for one small casting used in a rather complicated mechanism, produced in large quantities. Our superintendent visited this plant, and after inspecting the various castings, suggested that malleable castings could be substituted for some gray iron castings at little increased cost, and the trouble that had been experienced with breakage could be entirely eliminated. The customer, of course, was skeptical as usual, but was finally persuaded to allow our superintendent to make up a sample handle lever. The design was carefully studied, a wood pattern was made, and a few sample castings produced. The customer was so pleased with the advantages of these malleable castings, that he immediately changed eight other parts to malleable, and our business from this one concern was increased many times. In addition to this, another concern producing the same character of equipment, was induced to make similar changes in its equipment. It seems needless to say that the foundry assumed considerable responsibility in inducing the customer to change his source for material, yet recognizing that responsibility, the change worked out admirably for the customer. In this instance, the customer had to be educated to the fact

that malleable castings cannot be produced in the same time as gray iron castings, and considerable coaching of the production and purchasing departments was necessary, until they became accustomed to the delivery requirements for malleable castings. The problem now, is to continue to furnish satisfactory castings within a reasonable time, so that our friends the gray iron people, cannot recapture this business.

These simple illustrations are the kind every foundryman runs into every day. I might have referred to increased production from the use of mold conveyors in conjunction with continuous pouring; to the use of permanent molds now being experimented with by at least one malleable foundry and which are in use in numerous gray iron and non-ferrous metal foundries. Results from these installations have been spectacular, to say the least, and all the result of research work. But these late achievements are confined to so few foundries that illustrations of this kind have been purposely avoided.

All of us have profited from the research work of the splendid organizations that are supplying the foundries with equipment and supplies. Our foundry researchers should, and do co-operate with the researchers of these supply organizations to the end that the best possible equipment can be supplied. It is through the co-operation of these supply researchers that some foundries are provided with sand handling and conditioning equipment, that permits the handling of the sand with a minimum cost, and also gives a uniform sand condition. Molding machines have been greatly improved, and today we are in a position to secure machines that will stand up day after day with very little attention. The former methods of firing furnaces and annealing ovens have been supplanted by the more advanced method of using pulverized coal. Electric furnaces are coming into use. Tunnel annealing ovens have supplanted the batch type of ovens in a number of foundries, and splendid results are being obtained, not only in controlling temperatures, but in reducing the time of the annealing cycle. Conveyors are commencing to take the place of man power in handling the molds from the bench to the floor, or to the furnace, and other conveyors are used for handling the castings from the shake out floors to the cleaning rooms, and again from the cleaning rooms to the annealing ovens, and from the annealing ovens to the shipping department. We have bet-

ter grinders and better grinding wheels; superior flasks; more uniform refractories, and is it not fair to say that all of these improvements have been brought about by intensive research work on the part of the suppliers in co-operation with the foundry executives?

We cannot be satisfied with these accomplishments. We must continue to research into those jobs in which progress has been made. Research work requires effort and lots of it. It requires clear thinking. Because production has been doubled, does not mean satisfaction. A true researcher is never satisfied. Sometimes a researcher falls into a rut. He thinks perfection has been reached. He has made progress with a certain job, and is satisfied. When we are satisfied, progress will stop. We, in the malleable industry, know that we cannot stop. We must do everything possible to improve the quality of our product. We cannot be satisfied to just uphold the quality. We still have much to do. Our customers are more exacting. I doubt if we have always realized how much the increased exactingness of our customers has actually increased our cost of production. For a time there seemed to be a tendency for some of the big users of malleable to substitute other materials. Apparently, the pendulum swung too far. Every few days we hear of some job coming back to us.

I have mentioned increased production and lower costs that have enabled us to secure additional business. We have lost, perhaps, just as much business because other foundries have been more progressive in the production of certain castings. It is not just a question of improving methods so that you can take some business away from another malleable foundry—it sometimes means saving that tonnage for the malleable industry. The malleable foundry industry must forge ahead, even though this big branch of industry is represented in progressive methods by only a few foundries. Eventually, they will get the cream of the business and the less progressive ones—the non-researchers—will pass out of the picture.

With this changed situation, may we not hope for a proper recognition of the industrial and economic value of good malleable castings, and command prices for these castings that will be commensurate with the time and effort required for their production.

Refractories for the Cupola

By C. E. Bales,* Ironton, Ohio

Although the gray iron foundry ranks fifth in the consumption of clay refractories, the subject of cupola linings has been given comparatively little study. This has been due, not entirely, to lack of interest on the foundryman's part, but rather to lack of definite knowledge of actual service conditions and not knowing just what properties the cupola block should have, to give the best service.

Cupola blocks have been manufactured for many years in all the fire brick producing districts and although it is well known that some blocks give much better service than others, the foundryman has taken neither the time nor trouble to find out why. Until recently, he has been willing to accept most any type of fire clay block believing that the cheapest material was the most economical.

During the past three years the larger foundries have become interested in this problem and they have found that by proper selection refractory costs could be reduced materially, although the initial cost of the brick might be higher.

It is the purpose of this paper to describe in a general way the various processes by which cupola blocks are made, their properties and their behavior in service. A description of our present tests is also included as well as a suggested method for selecting suitable cupola blocks.

Raw Materials

The highest grade fire clays occur in Pennsylvania, Missouri, Ohio, Kentucky, New Jersey, Colorado and Maryland. These clays vary widely in chemical and mineralogical composition. Most of the New Jersey clays contain an excess of silica, while some of the Missouri clays contain an excess of alumina. The-

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oretically pure clay has the composition Al_2O_3. $2SiO_2$. $2H_2O$ corresponding to 39.8 per cent alumina, 46.3 per cent silica and 13.9 per cent water. Even the purest flint clays and kaolins contain small amounts of impurities such as iron oxide, titania, lime, magnesia, soda and potash, and some of the plastic clays contain greater percentages of these impurities.

The clays used in the refractories industry for cupola blocks are flint, semi-flint and plastic clays. These clays are obtained by drift, open pit and shaft mining methods and are then transported to the fire brick plant, which may be located at a considerable distance from the mines. When the clay is received at the brick plant it is either stored in large piles where it is allowed to weather or it is crushed and conveyed to storage bins.

Cupola blocks are made from fire clays with a small amount of grog in the form of burned clay or brick bats. Some plants use a mixture of flint clay, plastic clay and grog; some a mixture of semi-flint clay, plastic clay and grog, while others simply use a clay of the semi-flint or plastic type with just enough grog, made from the same clay, to control shrinkage and prevent cracking. The use of one clay or a blend of clays having the same thermal characteristics is undoubtedly the best practice, because as has been indicated by Geller[1] it is possible for a block to fail from stresses within the structure caused by the differential thermal dilatation of the various materials used in the block, even though the heating or cooling is uniform throughout the body. Some clays exhibit twice as much thermal expansion as other clays and it is obvious that if two such clays are used in the production of cupola blocks, these blocks will be highly strained during the manufacturing process as well as when heated in actual service. Naturally such blocks will fail more readily than blocks whose constituents expand and contract uniformly.

Methods of Manufacture

Three methods are used in the production of cupola blocks. They are made by the hand made, stiff mud and dry press processes. The raw material is conveyed from the storage piles by a belt or drag conveyor to a dry pan where it is crushed. The

[1] American Refractories Institute, Technologic Paper No. 4, Oct., 1927.

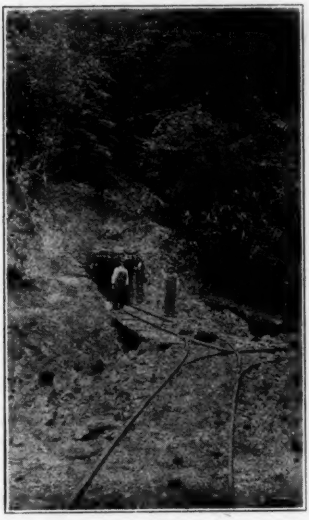

FIG. 1—ENTRANCE TO FIRE CLAY MINE

FIG. 2—INSIDE VIEW IN FIRE CLAY MINE

FIG. 3—MOLDING CUPOLA BLOCKS BY HAND

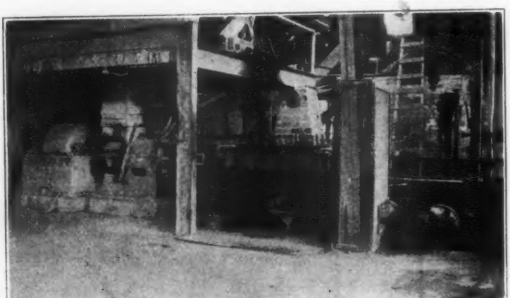

FIG. 4—MACHINE FOR MOLDING CUPOLA BLOCKS

material passing through the perforated bottom is screened and conveyed to storage bins.

Hand Process

In the hand made process definite quantities of clay and grog are drawn from the bins, placed in a wet pan and the required amount of water is added. The batch is then ground until the clay is of the proper fineness and stiffness. The best cupola blocks are made from very stiff mud. The batch is then removed from the wet pan by a mechanical emptier and then conveyed to the molding tables.

Unless considerable care is exercised in the molding of cupola blocks they will contain oil or sand cracks which will decrease the life of the block in service. A piece of mud called the "walk" is rolled until it is solid, has a smooth surface and approximates the shape of the mold. The "walk" is thrown into the mold, jolted several times on a bumping block, the excess mud cut off with a wire and then the surface is slicked. The mold is then carefully dumped on a hot floor where the block remains until it is thoroughly dried. They are then set in a kiln where they are fired to a high temperature. The best cupola blocks are fired at Cone 10 to 12, which is approximately 2400 degrees Fahrenheit.

Stiff Mud Process

In the stiff mud process the clay batch is tempered in a pug mill and the plastic mass molded by being extruded in the form of a long column, through the die of a brick machine. The column is cut automatically into blanks of approximately the size and shape of the finished block and they are then run through a power press where they are pressed to the desired size, branded and the corners filled out. The blocks are then placed on small cars, run in tunnel dryers where they are thoroughly dried and then set in the kiln for firing.

Dry Press Process

Dry press blocks are made by crushing the clay in a dry pan and adding sufficient water at this point so that the clay grains will hold together when pressure is applied. Some plants crush the clay dry and add the water later in a pug mill type mixer.

The damp clay is conveyed to an agitator located directly above the dry press machine and is thoroughly stirred so that the coarse particles and the fines are intimately mixed.

The clay is fed through chutes into the charger of the brick machine, the mold box is filled out and the block molded under a pressure of about 4,000 pounds per square inch. The blocks are either set direct in a kiln or placed on dryer cars for drying. It is necessary to burn dry press blocks at a higher temperature than either hand made or stiff mud blocks.

Burning

Cupola blocks are set in the upper parts of the kiln and also around the rim, since it is in these positions that the highest temperatures are obtained.

It requires about two weeks to fire and cool a kiln of fire brick. The temperature is brought up gradually until all the water is removed from the brick and then raised still higher until the chemically combined water is driven out and the clay thoroughly oxidized, that is, the carbon is burned out and various mineral constituents dissociated. The brick are then subjected to a soaking period, flashed, and then allowed to cool slowly. Thermoelectric pyrometers are used during the heating up period and pyrometric cones used during the finishing period.

Properties of Cupola Blocks

Cupola blocks made by these different processes have different characteristics and if the foundryman is to obtain maximum service from his lining, it is necessary that these properties be taken into consideration.

Hand made blocks are generally of a medium grind, somewhat porous, have the maximum resistance to rapid temperature changes, but are only moderately resistant to abrasion and slag action.

Stiff mud blocks usually have a fine grind, are very dense, moderately resistant to rapid temperature changes and have excellent load carrying ability. Where conditions of abrasion and slag action are unusually severe, they perform better than any other type of block.

Dry press blocks are of fine grind, very porous, have good

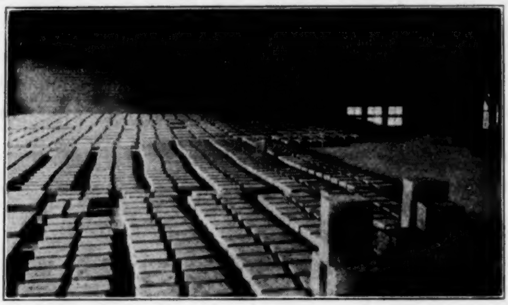

FIG. 5—DRYING CUPOLA BLOCKS

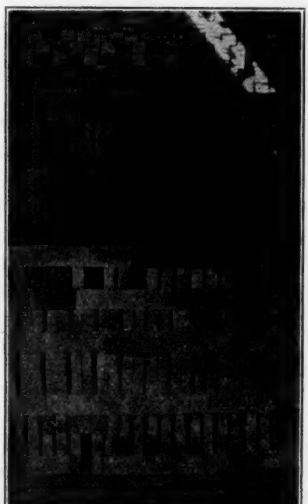

FIG. 6—CUPOLA BLOCKS IN KILN

resistance to rapid temperature changes, but their resistance to abrasion and slag action is only fair. Not many dry press blocks are being used in cupola practice, although there are a few cases where they apparently give good service.

Table 1 shows the chemical and physical properties of hand made and stiff mud, machine made cupola blocks, that have given successful service under a wide variety of operating conditions.

Table 1

Chemical Analysis:	Hand Made	Machine Made, Stiff Mud
Silica	60.04	60.04
Alumina	34.41	33.22
Iron Oxide	1.51	1.83
Titania	1.20	0.99
Lime	0.44	0.70
Alkalies	2.25	2.32
Magnesia	0.62	0.50
P. C. E. (Fusion Point)	Cone 30-31	Cone 30-31
Standard Load Test (25 lbs. per sq. in (2462°F)	4.0%	4.6%
Standard Reheat Test (5 hrs. at 2552°F)	0.3% Expansion	1.05% Expansion
Spalling Test (2462°F—2" dip in water)	8% Loss—10 dips	30% Loss—10 dips
Basic Slag Penetration	1.50 sq. in.	0.61 sq. in.
End Cold Crushing Strength	2300 lbs. per sq. in.	5400 lbs. per sq. in.
Modulus of Rupture	1100 lbs. per sq. in.	1600 lbs. per sq. in.
Porosity	22.7%	12.0%
Apparent Specific Gravity	2.58	2.47

Behavior in Service

The Joint Committee on Foundry Refractories of the American Foundrymen's Association and the American Ceramic Society has a sub-committee on survey of the gray iron foundry and they are now studying actual operating conditions in the cupola. When this survey is completed we will have accurate data on just what service conditions the cupola lining has to withstand.

Several excellent papers[2] have been published on the conditions encountered in cupola practice and it is generally agreed that the blocks are required to withstand the following:

(a) Intense heat.
(b) Chemical corrosion.
(c) Thermal shock.
(d) Abrasion.

[2] *The Effect of Variations in Cupola Practice on the Life of the Refractory Blocks,* James T. MacKenzie, Jour. Am. Ceram Soc., Vol. 8, No. 11, Nov., 1925.
Refractory Requirements in the Gray Iron Foundry, Richard Moldenke, Jour. Am. Ceram. Soc., Vol. 8, No. 11, Nov., 1925.
A Study of Cupola Lining Refractories, G. S. Schaller, Transactions American Foundrymen's Association, Vol. 35, 1927.
The Selection and Use of Refractories for Iron Foundries, C. Presswood, Foundry Trade Journal, Vol. 38, No. 596, Jan. 19, 1928.

The cupola may be divided up into four parts: (1) the zone above the charging door, (2) the zone between the charging door and top of melting zone, (3) the melting zone proper, and (4) the crucible.

The conditions above the charging door are not at all severe and need not be considered further.

That part of the lining between the charging door and top of melting zone is subjected to severe abrasion, especially if the charging is done carelessly. Abrasion is a very important cause of failure, in fact some foundries never reline on account of failure at melting zone—they reline because the upper blocks wear out. Near the top of the melting zone the blocks are not only affected by abrasion, but they are subjected to a high temperature and particles of slag and molten iron are blown against the lining, which may cause small flakes of brick to spall off.

In the melting zone the blocks are subjected to a very high temperature, chemical corrosion from iron oxide, coke ash, flux, and the slag, and to thermal shock. The latter is very severe when the door is dropped and water turned on the lining.

In the crucible the lining is subjected to high temperatures, molten iron (although this is unimportant unless it contains considerable iron oxide), and thermal shock.

It has been determined[3] by actual measurement that temperatures above 3,000 degrees Fahr. exist in the melting zone of the cupola and such a high temperature, combined with the corrosive action of iron oxide and slag make it necessary that a block of high refractoriness be used if the best service is to be obtained from the lining. Cupola blocks with a P. C. E. of Cone 26 (approximately 2,900 degrees Fahr.) have been used, but a recent survey made in several foundries using such blocks indicates that the service obtained is not satisfactory.

In some cupolas a large amount of iron oxide is formed which comes into contact with the lining either in slag or as the oxide itself. Iron oxide is one of the most active fluxes known, especially when the atmosphere is reducing and when the temperature is above 2,400 degrees Fahr. The formation of this

[3] Foundry, *Cupola Gases and Temperatures*, A. W. Belden, Bureau of Mines, Bulletin 54.

oxide or burned iron is partially under the control of the operator and should be kept at a minimum to prevent excessive erosion.

A large malleable foundry was melting in a cupola and refining in an electric furnace. Considerable steel scrap was included in the charge and for metallurgical reasons the minimum amount of coke was used. A large amount of iron oxide was formed, the slag was bluish black and very porous and a six-inch lining in the melting zone was destroyed each day. It was an excellent example of the action of iron oxide on clay blocks at high temperatures.

Some cupola linings fail from spalling. This is caused by rapid temperature changes, cracking produced by vitrification and

FIG. 7—KILNS FOR BURNING CUPOLA REFRACTORIES

shrinkage, slag penetration and the pinching effect produced by improper construction. In actual practice these conditions are brought about by the necessity of heating up the cupola in a few hours, cooling down with a stream of water, the charge deflecting the air blast at intervals so that cold air blows on the hot lining, particles of molten iron and slag being blown against the lining and lack of care in chipping off the slag preparatory to daubing the melting zone.

The ultimate failure of the cupola lining is usually brought about by a combination of the four factors of destruction, listed above. In rare cases linings have been known to fail from some one definite factor, but in such instances the blocks were either of inferior quality or the cupola operation was poor.

Fire Brick Tests

The laboratory tests most commonly made on cupola blocks are the following:

- Chemical Analysis
- P. C. E. (Fusion Point)
- Spalling Test
- Crushing Strength
- Porosity

Chemical Analysis

To an experienced man, the chemical analysis of a cupola block will give a general idea of its refractoriness. Even though considerable study has been made on the subject, there is as yet no rule whereby the ultimate refractoriness can even be closely determined from the chemical composition. Failure occurs frequently because of certain physical characteristics that are influenced only indirectly by the chemical composition, and for this reason the analysis should not be made an important factor in the selection of blocks except for certain specific conditions. In the cupola it is very doubtful if small differences in composition would make any difference in the service obtained.

P. C. E.

This is the oldest and most prominent test used in connection with refractories. It was formerly known as the fusion or softening test, but these terms were not entirely accurate, so the name has been changed to *pyrometric cone equivalent* or simply P. C. E. The P. C. E. value of a cupola block is made by determining the temperature at which the tip of a cone made from the ground block will bend sufficiently to touch the base in which the cone is held. In the standard test the rate of heating and the furnace atmosphere is controlled.

The value obtained in this test is not the safe working temperature of the block, as is so often assumed, but it is really the end point and should be used only as a figure by which a general comparison can be made with the refractoriness of another sample tested in the same manner.

Spalling Test

The spalling test as ordinarily conducted consists of alternately heating the ends of samples of brick to a prescribed temperature and cooling them either in water or in a blast of air. The original test consisted of heating the ends to 2462 degrees Fahrenheit and then dipping in four inches of water. The test has been modified now so that after heating to 2462 degrees Fahrenheit the brick is dipped in two inches of water. This produces a more gradual loss and less erratic behavior than the four-inch test. Dipping in the four inches of water frequently caused the test brick to break in half, while spalling in service usually takes place by corners and comparatively thin sections breaking off. After the test bricks have been subjected to 10 or more dips they are weighed and the loss in weight reported as the spalling loss on so many dips.

The water dip test simply shows thermal spalling. In the cupola spalling may occur from other causes and we need a test that will show just how a block will hold up in service. Such a test is being developed now at Mellon Institute. Instead of testing single brick a number of samples are laid up in a panel and subjected to heating, then cooling, by an air blast. It is possible to apply pressure to the brick in the panel and also to apply a coating of slag to the heated face. In this manner actual service conditions may be simulated.

Cold Crushing Strength

In this test the brick are placed on end in a compression machine of the Riehle type and a record kept of the pressure necessary to crush the brick. The result is expressed in pounds per square inch. This test is of value in judging the resistance of the material to abrasion. Usually the greater the mechanical strength, the greater the resistance to abrasion.

Porosity

This is commonly determined by saturating small pieces of the block with water or kerosene and weighing on a specific gravity balance. The porosity is obtained from the dry, suspended and saturated weights. This test is of value in judging the resistance of the block to slag penetration.

Selection of Cupola Blocks

The ideal cupola block would be one with high refractoriness, one that would withstand rapid temperature changes without spalling, and one that would be very resistant to abrasion and slag corrosion. It is difficult to find any one block that has these properties developed to the highest degree, and for that reason it is necessary that wise judgment be used in the selection of cupola blocks.

Some blocks are sufficiently refractory, but they fail from abrasion. Others are very strong mechanically and resistant to abrasion, but they will not stand the high temperature and slag action of the melting zone. There are a number of blocks on the market whose refractoriness and other physical properties would enable them to give good service, but operating conditions are such that they are not given a fair chance.

In order to obtain a block that will give maximum service it is necessary that the foundryman do a little experimenting and make a critical study of his cupola operation. Secure the assistance of an engineer experienced in the application of refractories. A number of fire brick plants have such engineers on their staffs and are usually more than glad to extend this service to you. Run some actual service trials in your cupola, keep an accurate record of their performance and you will soon determine just what block will perform best under your operating conditions.

Some foundries use a machine made block throughout the cupola, others can only use a hand made block. Where spalling conditions are severe, the hand made block is probably the best, but for operations where abrasion and slagging are severe, the dense machine made blocks give the best results. It is possible that a combination of machine made blocks for the charging zone and hand made blocks for the melting zone would be the solution to the service problem. It would be inconvenient, probably, to have two kinds of blocks in stock, but the greater life of the brick lining might overcome this objection.

Daubing Material

No cupola blcok would last longer than two or three days in the melting zone unless it was patched and daubed after each heat. There are probably as many daubing mixtures as there are gray

iron foundries. A great deal has been written on this subject and it is well known that the daubing material can either make or ruin the lining in the melting zone.

A good grade of plastic fire clay should be used, mixed with about 50 per cent of either crushed brick bats or white silica sand. Yellow loam or shale should not be used as they have a low fusion point, will flow down the lining as soon as the cupola is hot, thus leaving the brick exposed, and frequently poor daubing is the cause of bridging in the cupola.

One gray iron foundry, running very hot iron, was experiencing difficulty with their lining. They would burn out a six-inch lining within a week. It was found that they were using a mixture of one-third fire clay and two-thirds red molding sand. The fire clay had a P. C. E. of Cone 32 (3,092 degrees Fahr.). The red sand softened at Cone 11 (2,417 degrees Fahr.) and the mixture had a P. C. E. of Cone 16 (2,669 degrees Fahr.). The hottest part of the cupola was 2,900 degrees Fahr. and at this temperature the patching material melted, carried down the split brick used in repairing and the block lining was severely corroded. A daubing mixture of fire clay and brick dust was then used and the trouble ceased.

Careful daubing will preserve the lining.

Some Recent Developments in Cupola Metal

By John D. Miller,* Philadelphia, Pa.

We have been hearing much about air and electric furnace gray iron castings having very superior physical properties compared with those made in the cupola furnace. As it has been our endeavor to produce the best quality material possible, we investigated these claims and obtained representative figures on the physical properties of each and find by comparison their tensile strengths run from 10 per cent to 20 per cent higher than cupola metal but they cost from 25 to 50 per cent more. It seems to us, therefore, that on account of the difference in production costs the comparison is unfair to cupola iron.

At our plant we began to study the effect of high steel mixtures; that is, from 50 to 98 per cent steel in the charges. Not only did we carry out a long experimental program ourselves but we sought the cooperation of others who are working along the same lines.

The purpose of this paper is not only to give the results obtained by the cooperative efforts but to outline in considerable detail some of the problems encountered that are, as we see them, essential, particularly as to the method of operating cupolas for melting high percentages of steel; control of chemical composition; the effect of high percentages of steel on structure and the increase in physical property values obtained when nickel is used.

Methods of Operating Cupola for Melting High Percentages of Steel

When foundrymen began to charge steel with their iron mixtures in their cupolas for making castings, it was immediately necessary to give more attention to cupola operations as relate to volume of air; pressure at which it enters the cupola; arrange-

*General Superintendent, Cresson-Morris Company.

ment of tuyeres; quality of coke; size and arrangement of charges and the amount of coke both on the bed and between the charges. In melting still higher percentages of steel, it is imperative that these same factors be extended in order to successfully and uniformly produce the desired materials. These are important on account of their effect upon chemical analyses and will be discussed later.

It should be borne in mind that any cupola operates in accordance with the manner in which the coke is burned. Ideal combustion of the fuel in cupola operation is a uniform temperature throughout the whole area in a well-defined zone. This, however, is very difficult to control because the air entering the area adjacent to the tuyere openings has both a richer oxygen content and a higher velocity and diminishes in these respects as it is driven to the center of the cupola. This produces a cone-shaped combustion area, because of more rapid burning of the fuel around the cupola walls and results in more rapid melting in this section than in the center of the cupola. For this reason, the cupola should be charged with the slow melting materials of the charge around the walls and the lighter and less bulky material in the center of the cupola. Inasmuch as steel in a cupola charge melts more rapidly than pig iron, it should be charged on top of the pig iron.

The charges should be of sufficient size to permit a definite separation of each charge as such by the necessary amount of coke, using a ratio between 6½ and 7½ to 1.

The height of the bed is very important as is also complete ignition of the fuel before charging to store up a sufficient amount of heat in the bed to guarantee rapid melting when the blast is put on. The height of the bed varies in different practices from 30 to 48 inches above the top of the tuyeres, depending upon the variables among cupolas and quality of coke and percentage of steel used. The height of bed then will have to be very largely a matter of experiment for each individual cupola.

Control of Chemical Composition

In ordinary cupola practice, using stock of uniform composition, it is a comparatively simple matter to forecast with reasonable accuracy the final analysis of the resulting metal. In this

case, there is a certain oxidation loss of silicon and manganese; practically no change in carbon and phosphorus and a reasonably uniform pick-up in sulphur. High percentages of steel, however, make it more difficult to accurately calculate the chemical composition of the resulting metal unless such factors as uniform melting temperatures, time that the liquid metal is held in contact with coke in the well, uniform rate of melting and accurately dividing the charges by tapping each charge out as soon as it is melted, are maintained, because of the influence of these conditions on total carbon.

Many investigators and foundrymen at one time considered that steel melted in the cupola was carburized by its contact with the coke and carbonaceous gases rather than absorbing carbon in the liquid state, due to its contact with the coke in the cupola well. This view, however, has been proven at least partially erroneous since a carbon content ranging from less than 2 per cent to more than 3 per cent can be secured from the same mixture, depending upon whether the iron is permitted to run from the cupola as fast as it is melted or allowed to accumulate in the bottom of the cupola in contact with the coke. This demonstrates that control of total carbon depends upon the manipulation of the cupola as well as the composition of the charges.

Also, there seems to be a very definite effect, when operating a cupola under these conditions, on silicon loss by oxidation. Instead of the normal silicon loss, there results under certain conditions when melting high percentages of steel an actual pick-up in silicon content. There seems to be no real reason to believe that there is an actual reduction of silicon in the cupola but a uniform increase of silicon content beyond that calculated in the mixture has been observed by several foundrymen with whom we have discussed the subject and, in order to correctly predetermine the silicon content, it is necessary in practice to allow for a pick-up of between 10 and 20 points. Whether the silicon is reduced from the silica in the ash of the coke, the cupola lining or from the sand bottom is a matter of conjecture. The fact that there is a larger loss of manganese when melting high steel charges than with the lower percentages does not cast any light on the question of silicon pick-up. On the contrary, it makes the problem more perplexing, and we hope some of our technical

friends will be able, in the near future, to offer an explanation for this phenomenon.

The Effect of High Percentages of Steel on Structure

Generally speaking, foundrymen have found that there is a definite relation between the silicon content desired in a casting and the percentage of steel that may be used to effect grain-refinement, and that they cannot continue to raise the silicon content and increase the percentage of steel beyond certain limits, as the increased percentage of silicon seems to open the grain rather than to progressively refine it. (See Table 1.)

There are perhaps two reasons why partial steel charges produce a better structure in a given analysis than pig iron and scrap; the first being that steel is a purer product than pig iron and contains no excess carbon as does pig iron, and consequently assists in carrying into solution as combined carbon some of the excess graphite in pig iron. The second reason, equally as important as the first, is that the melting point of steel is higher than pig iron and consequently produces a higher temperature metal and, as a result, assists also in forming combined carbon from the excess graphite in the pig iron. It does not seem to the writer that steel under 30 per cent, or even as high as 50 per cent, necessarily reduces total carbon, as he has found that total carbon remains fairly constant, regardless of the amount of steel used, when the same cupola practice is employed. (See Table 2.)

Increase in Physical Property Values by the Use of Nickel and High Percentages of Steel

About two years ago our attention was called to the fact that we could lower the silicon content of a 35 per cent steel mixture and add about twice as much nickel as we reduce the silicon and still maintain a readily machinable casting without the customary white edges and hard spots. As a result of this, we conceived the idea of reducing the silicon and increasing the percentage of steel, adding a sufficient amount of nickel and accomplishing the same results. By this procedure we found that we consistently improved our physical properties and at the same time maintained a uniformly progressive grain-refinement and strength as well as

good machinability as the percentage of steel was increased. With a given total carbon content and the use of silicon alone, we have been unable to even approximate uniformity of structure, grain-refinement or strength of that obtained by the lower silicon with nickel, because in those sections that cool more slowly graphite flakes are much larger and the combined carbon lower due to the difference in the graphitizing effect of silicon and nickel. (See Tables 3 and 4.)

Tabulation of Results Obtained from Increasingly High Percentages of Steel

We do not claim originality for the thoughts brought out in this investigation, but have simply tabulated results secured in our own foundry along with other thoroughly reliable and accurate data we have been able to secure. We have also tabulated the effects of material; cupola manipulation; composition and temperatures on structure and physical properties of gray iron made in the cupola. Great care has been exercised in eliminating any freak results and only those that have been duplicated consistently are furnished for your attention. While the results given here are not averages, they are representative, having been taken from heats that are representative of the mixtures and the test bars taken from work-a-day records.

An examination of the Tables 1 to 4 indicates that in the practice in our shops for a 3.23 per cent total carbon and 1.92 per cent silicon, the best tensile strengths are given with the 20 per cent steel mixture, and that increasing percentages of steel do not necessarily decrease the percentage of total carbon or produce an additional grain-refinement.

Table 2 indicates that by lowering the silicon content and increasing the percentage of steel, a higher tensile strength is produced. With increasing percentages of steel up to 60 per cent, the mixture analyzing 3.29 total carbon and 1.59 silicon, a maximum tensile strength of 36,110 pounds is given; while a 65 per cent steel mixture, analyzing 3.12 total carbon and 1.29 silicon, has a lower transverse strength and is too hard to machine to secure a test bar.

Table 3 indicates clearly that as the silicon or total carbon content is lowered and the iron is kept gray with nickel, the

Table 1

No.	Per Cent Steel in Charge	T. C.	Si	S	P	Mn	Ni	Standard Arbitration Bar, Pounds Transverse Strength	0.798" Diam. Bar, Tensile Strength Pounds Per Square Inch
1	15	3.37	2.00	0.096	0.43	0.68	...	3,710	31,200
2	20	3.23	1.92	0.104	0.39	0.71	...	4,080	32,080
3	25	3.32	1.97	0.109	0.37	0.64	...	3,940	31,840
4	30	3.35	2.01	0.112	0.36	0.69	...	3,860	31,620
5	35	3.40	1.99	0.110	0.35	0.62	...	3,790	31,440
6	40	3.37	2.04	0.098	0.34	0.64	...	3,820	30,780
7	45	3.39	1.92	0.106	0.35	0.72	...	3,810	31,020

Table 2

No.	Per Cent Steel in Charge	T. C.	Si	S	P	Mn	Ni	Standard Arbitration Bar, Pounds Transverse Strength	0.798" Diam. Bar, Tensile Strength Pounds Per Square Inch
1	50	3.40	1.44	0.096	0.32	0.80	...	4,310	33,760
2	55	3.37	1.54	0.102	0.34	0.73	...	4,400	34,020
3	60	3.29	1.59	0.117	0.24	0.62	...	4,580	36,110
4	65	3.12	1.29	0.108	0.19	0.66	...	4,180	(*)

*Too hard to machine.

Table 3

No.	Per Cent Steel in Charge	T. C.	Si	S	P	Mn	Ni	Standard Arbitration Bar, Pounds Transverse Strength	0.798" Diam. Bar, Tensile Strength Pounds Per Square Inch
1	65	3.06	1.21	0.120	0.19	0.73	0.64	4,640	39,780
2	70	3.32	0.82	0.115	0.18	0.80	1.27	4,730	41,110
3	80	3.24	0.68	0.121	0.19	0.67	1.54	4,860	43,160
4	90	3.09	0.76	0.104	0.112	0.63	1.96	5,330	46,720
5	97.5	2.82	1.26	0.113	0.076	0.61	1.84	5,740	55,780
6	97.5	2.76	2.59	0.070	0.12	0.65	1.11	6,740	60,440
7	97.5	2.72	2.29	0.087	0.096	0.93	1.74	5,720	58,250
8	97.5	3.16	1.54	0.120	0.065	0.72	1.91	6,110	60,800
9	98	3.25	1.41	0.109	0.079	0.68	1.57	5,780	55,690

Table 4

No.	Per Cent Steel in Charge	Per Cent Remelt	T. C.	Si	S	P	Mn	Ni	Standard Arbitration Bar, Pounds Transverse Strength	0.798" Diam. Bar, Tensile Strength Pounds Per Square Inch
1	80	20	3.09	1.62	0.112	0.097	0.64	1.62	5,730	53,460
2	80	20	3.16	1.36	0.108	0.073	0.72	1.41	5,940	55,310
3	70	30	3.25	1.41	0.113	0.096	0.62	1.96	6,030	58,470
4	70	30	3.36	1.56	0.104	0.062	0.70	1.11	5,310	49,140

physical properties are consistently increased up to the point where the entire charge is composed of steel except such percentages as are necessary for the proper amounts of 47.5 per cent ferro-silicon and 80 per cent ferro-manganese to furnish the desired composition.

Table 4 shows that under the same practice and control a remelt as high as 30 per cent together with 70 per cent of steel, less the necessary concentrated alloys, may be used in the cupola furnace.

It is our belief that these values are much in excess of those possible to obtain in plain cast iron by either the air or electric furnace processes, and it seems to us that in making quality castings, while there may be other elements to be considered, such as the question of raw materials and control that may be more easily accomplished by these methods of melting, they are certainly not more economical. The field for improvement and research on cupola metals is certainly very inviting to those who desire to produce a high grade materials in gray iron castings.

Committee on Foundry Sands

Report of Sub-Committee on Grading

To the Members of the American Foundrymen's Association:

During the past year the system of grading* tentatively adopted by the A. F. A. has made rather slow but definite progress. Several producers are now listing their sands according to the standard classification, and a number of foundries are ordering sand on A. F. A. numbers. The list, however, is rather small. There is still a strong tendency to cling to the old numbers which differ widely among themselves for the sand grades; in some cases the same sand is sold under two or three different numbers—these numbers being the ones with which their customers have been acquainted. However, the advantages of a common system of grading and a common language for describing sands is gradually becoming more apparent. During the past two months the chairman has had several requests from producers for help in grading their sands according to the A. F. A. method, all of which is encouraging.

Among the comments or criticisms that we have received, there is one in particular that may be of general interest. A producer of blended sands believes that pan material should be classed with the clay in determining the grade of a sand. This would give a lower grain fineness figure and a higher clay content. New zone limits would then be desirable. This producer finds that the pan material is almost directly proportional to the clay content of his sands, either as mined or when blended. This indicates that the clay bonding material in his deposits consists largely of what we now classify as clay and pan material. While this may be true for these deposits, it remains to be seen whether or not it is generally true. Furthermore, we would offer the thought that the definition of a clay should be determined by its

**Tentative Standard Grading Classification for Foundry Sands,* Trans. A. F. A., Vol. 35, pp. 193-197 (1927).

FIG. 1—TYPE OF SAND GRAINS CLASSIFIED AS ANGULAR (PHOTO-MICROGRAPH BY HANLEY)

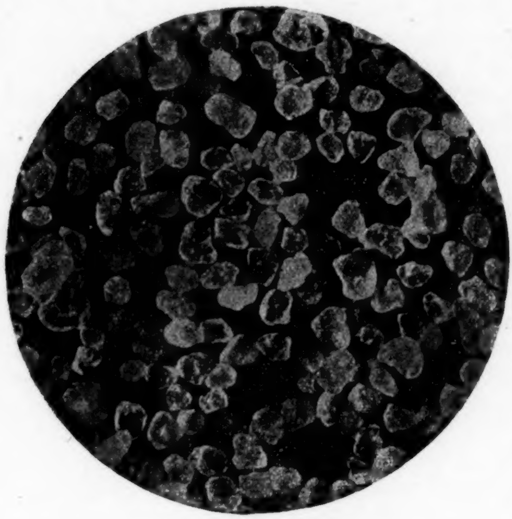

FIG. 2—TYPE OF SAND GRAINS CLASSIFIED AS SUB-ANGULAR (PHOTO-MICROGRAPH BY HANLEY)

effect on molding properties rather than by the way it is found in nature. There is some opinion supported by experimental evidence that even the coarser part of what we now call clay functions as grain and possibly should be classified as grain. For the present, the sub-committee has not seen fit to change the clay classification.

Grain Shape

For some time the sub-committee has been considering standards by which to describe grain shapes. The terms *angular, sub-angular* and *rounded* were proposed and photographs of typical sand grains of each type were prepared. These terms, together with the illustrative photographs of Figs. 1, 2 and 3, are now proposed as tentative standards. Credit is given to H. B. Hanley of Whitehead Brothers Company for the photographs.

Grading Zones

It has been suggested by several users of the grading system that the zones are too wide. After considering the matter, the

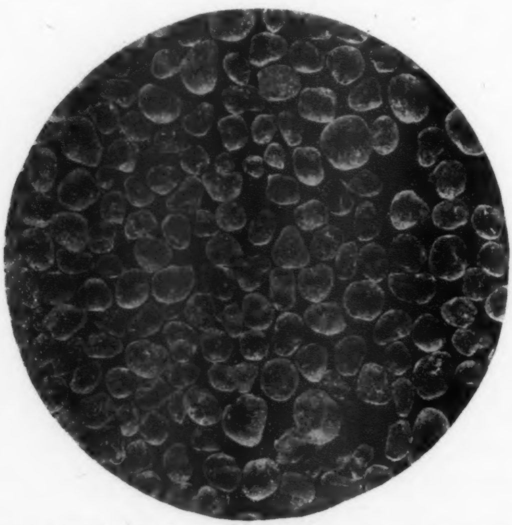

FIG. 3—TYPE OF SAND GRAINS CLASSIFIED AS ROUNDED (PHOTO-MICROGRAPH BY HANLEY)

committee has recommended the terms *fine* and *coarse,* which may be used to further define the grain fineness of sands. For example, a fine No. 2 sand has a grain fineness in the upper part of the 140-200 zone, and a coarse No. 2 sand is in the lower part of the zone. No further limits are set and it is our thought that these supplementary terms will be used only when there is particular need for them.

Additional Sieves

The Sub-Committee on Tests has recently added the 30 and 50 mesh sieves to the original standard set recommended for foundry sands. This raised the question as to what multipliers should be used for these sieves when calculating grain fineness. The sub-committee makes the following recommendations to care for these and other sieves that may be added:

The weight or percentage of sand on each sieve is to be multiplied by the "approximate mesh number" of the sieve through which it passed. Inasmuch as mesh numbers differ among the testing sieve makers for sieves of approximately the same opening, Table 1 is given listing the "approximate mesh numbers" or multipliers along with the actual mesh numbers which are listed.

Grain Distribution

Several methods for expressing grain distribution were proposed last year and were outlined in our report* at the Chicago

*Page 189. Trans. A. F. A., Vol. 35 (1927).

Table 1

ACTUAL MESH NUMBERS				APPROX. MESH NUMBER†
Tyler Standard		U. S. Standard		
No.	Opening in inches	No.	Opening in inches	
6	.131	6	.132	5
10	.065	12	.0661	10
14	.046	16	.0469	15
20	.0328	20	.0331	20
28	.0232	30	.0232	30
35	.0164	40	.0165	40
48	.0116	50	.0117	50
60	.0097	60	.0098	60
65	.0082	70	.0083	70
80	.0069	80	.0070	80
100	.0058	100	.0059	100
115	.0049	120	.0049	120
150	.0041	140	.0041	140
170	.0035	170	.0035	170
200	.0029	200	.0029	200
250	.0024	230	.0024	250
270	.0021	270	.0021	300

† —to be multiplied by the weight or percentage passing through this sieve and caught on the next sieve below it.

meeting. One of these methods—a modification of the one proposed by W. C. Hamilton—was given further consideration by the committee, and the secretary was asked to publish a description of it in the Sand Control Pamphlet.

Colloidal Properties of Clays

It is now fairly well established that the bonding strength of a clay, particularly its dry bonding strength, is very closely related to the fineness of subdivision of its particles. Highly colloidal clays—that is, those containing large percentages of particles the dimensions of which are in the neighborhood of a hundred thousandth of an inch or which are hydrated—are very sticky and when dried are exceedingly strong. These colloidal properties can be readily measured by the Tentative Standard A. F. A. Dye Adsorption Test.

The term "colloidal properties" is suggested to be used in this connection rather than "quality of clay." This latter term implies that a sand of low dye adsorption value has poor quality clay, which is not a fact. In other words, a sand of low colloid content is actually superior for some purposes. The dye adsorption values of good heap sands are seldom over 700, frequently less than 300. The most widely used and probably the most successful brass and aluminum sands are of comparatively low dye adsorption value. On the other hand, sands successfully used for dry molds are more highly colloidal—have higher dye adsorption values.

Colloidal properties are also a factor in the behavior of core sands. Sands of low dye adsorption value require less oil binder, and produce cores that bake hard but can be knocked out of castings readily.

These considerations point to the advisability of grading sands according to their colloidal properties. It is hoped that this can be made an active matter in the near future.

Respectfully submitted,

A. A. Grubb, *Chairman,*
Sub-Committee on Grading.

Committee on Foundry Sands

Report of Sub-Committee on Tests

To the Members of the American Foundrymen's Association:

As was reported to you last year, it appears that as time goes on the work of the committee instead of diminishing seems to increase, and as a result of this condition there has been much to occupy our attention during the past year.

While the Sub-Committee on Tests held only one meeting, much work of investigation in both the laboratory and foundry has occupied quite a little of the time of the individual members who have co-operated so heartily with the Chairman.

Pamphlet on Standard Tests

In June, 1924, the A. F. A. issued a pamphlet prepared by the Sub-Committee on Tests which contained a detailed description of the tests that had been recommended by the Committee up to that time as well as instructions for making them.

Since then, it has been found necessary to modify some of these tests, and the committee has also recommended additional ones. Because of this, it has been found desirable to bring this pamphlet up to date, and furthermore to divide it into two parts—I Standard Tests, II Control Tests.

R. E. Kennedy, Technical Secretary of the A. F. A., has devoted considerable time to this work during the past winter, and it was hoped to have at least the first part ready for distribution at this meeting but, owing to the fact that it seemed desirable for each member of the committee to go over the manuscript carefully, the completion of the work has been somewhat delayed. It will, however, be sent to press in a few days.*

*The revised test pamphlet has been published and copies may be secured through the secretary of the A. F. A., 222 West Adams Street, Chicago, Illinois.

Strength Test

There is perhaps no test of the properties of sand which has given the committee more concern than the strength test, and up to date no less than four methods have been suggested for determining this property, and a different type of machine devised for each one.

The strength tests as now recognized include the Doty Bar, Compression, Tensile and Shear Tests. Of the last mentioned there are two types, which might be called the single shear and the double shear.

While the committee has not up to this year recommended any one of these as a standard A. F. A. test for determining the strength of a sand, it has endeavored in the case of the first three to formulate a standard method for carrying out the test, and anyone using a machine for testing the strength of sand should see that it conforms in its operation to the standards set by the A. F. A.

During the past year, the committee, in order to obtain further light on the subject, requested several foundries to make daily tests of their sand by all four of the methods mentioned above, and those who kindly co-operated were the Ohio Brass Company, the Hunt-Spiller Mfg. Corp., and the Lebanon Steel Foundry. Additional work along the same line was done by Professor H. L. Campbell of the University of Michigan, and at the sand laboratory of Cornell University.

The committee feels that the introduction of so many different methods of testing the strength of sands may lead to some confusion in the minds of the foundrymen as to which is the best one to use. It, furthermore, believes that one method and only one should be recommended as a Standard Strength Test. For that reason, the Sub-Committee on Tests now recommends the Compression Test as a Standard A. F. A. method for determining the strength of sand.

In doing so, there is no intention to intimate that the other methods are valueless, for it is well recognized that for daily control work one type of machine may serve as well as another. In Appendix A there are given the results of tests made by the different machines at several different foundries.

Split Core Box vs. Brass Cylinder

It has been suggested that better results might be obtained in connection with the strength test if the standard 2 inch core were molded in a split core box, instead of being rammed in a brass cylinder and then removed by stripping. Some interesting figures on this point, based on a number of tests made by C. P. Randall of the Hunt-Spiller Mfg. Corp. are given herewith and indicate that there is comparatively little difference between the two methods.

Tests by C. P. Randall, Hunt-Spiller Mfg. Corp., Boston*

To determine whether or not a difference existed in the use of the split core box and the brass cylinder, a series of tests were made using sands from our regular heaps over a period of seven consecutive days. All readings were obtained on the Adam's compression machine.

The brass cylinder used was of the type adopted by the A. F. A. Sub-Committee on Sand Testing. The split core box was of cast iron in two halves with planed surfaces. The sections were held together by two C clamps. The box was of the same height as the brass cylinder with an inside diameter of two inches. The halves of the box were held in place by two pins, one on each side and at the top and bottom.

The results recorded in Table 1 offer data obtained through the use of the two methods.

From the data of Table 1 of 87 different tests, it was found that there was an average variation of 0.13 lbs. per sq. in. Results showed that the split core box gave figures which were slightly in excess of those from the brass cylinder. It was presumed that the brass tube would give readings higher than those obtained through the use of the split core box, because of the tendency to compress the sand when using the stripping post. This was not the case, however, and apparently the sand when once rammed is not affected by the force applied to remove the core from the cylinder.

From an average of 87 tests, there existed an error of only 1.5%. Since our sands run with a maximum compression of

*Chemist, Hunt-Spiller Mfg. Corp., Boston. The committee acknowledges the helpful cooperation given by the Hunt-Spiller Mfg. Corporation.

13 lbs. per sq. inch, an error as stated above would mean an almost negligible difference of 0.195 lbs. per sq. inch. The limit allowed in averaging two or more specimens taken from the same sand is at least 5%. Therefore, either the split core box or the brass cylinder may be used with practically identical results.

Table 1

TESTS CONDUCTED TO DETERMINE EFFECT OF USING SPLIT AND SOLID SPECIMEN TUBE HOLDERS FOR STRENGTH DETERMINATIONS

Sand No.	Compression in Pounds per Square Inch		Sand No.	Compression in Pounds per Square Inch	
	Split Core Box	Solid Box		Split Core Box	Solid Box
1	10.0	9.2	45	12.3	12.2
2	8.3	8.2	46	9.05	8.9
3	6.1	6.0	47	8.15	7.9
4	9.1	8.8	48	7.25	7.0
5	6.2	6.2	49	9.70	9.6
6	12.4	12.3	50	9.15	8.9
7	8.7	7.9	51	9.25	9.5
8	7.2	6.8	52	9.8	9.8
9	6.4	6.0	53	10.3	10.8
10	10.05	9.7	54	7.75	7.8
11	9.0	9.1	55	6.3	6.3
12	9.95	9.7	56	7.3	7.0
13	9.9	9.8	57	6.1	6.0
14	9.2	9.2	58	12.2	12.2
15	6.9	6.7	59	8.85	8.6
16	5.4	5.6	60	8.2	8.6
17	6.95	6.8	61	7.3	7.4
18	5.55	6.0	62	9.75	9.7
19	12.15	12.1	63	9.3	9.4
20	9.60	10.0	64	9.9	9.5
21	10.20	10.2	65	10.3	10.3
22	8.10	8.1	66	10.7	10.6
23	9.55	9.3	67	7.4	7.7
24	9.45	8.9	68	6.25	6.0
25	9.85	9.8	69	7.25	7.1
26	9.6	9.7	70	5.8	5.7
27	9.45	9.4	71	12.3	12.0
28	6.75	6.7	72	8.45	7.8
29	5.9	5.9	73	7.95	7.6
30	7.25	7.0	74	6.95	6.8
31	5.60	5.6	75	10.3	10.8
32	12.85	12.6	76	9.6	9.7
33	8.95	8.3	77	9.25	9.2
34	8.45	8.2	78	9.75	9.5
35	7.45	7.2	79	10.20	10.2
36	9.70	9.8	80	7.9	7.6
37	9.15	8.9	81	5.85	5.6
38	9.85	9.6	82	6.8	6.8
39	9.1	8.9	83	5.85	5.8
40	9.85	9.9	84	12.3	12.1
41	7.1	6.9	85	9.75	9.5
42	5.95	5.9	86	8.5	8.5
43	7.15	6.7	87	7.5	7.3
44	5.7	5.7			

Strength of Sands for Different Kinds of Castings

The committee has, from time to time, been asked for figures on the limiting values or range of values of the different properties which should be shown by sands used for one or another type of work. For example, what range of permeability and strength should a brass sand show?

It must be repeated that the Sub-Committee on Tests does not feel warranted yet in expressing an opinion on these points, but it does take pleasure in presenting a series of values obtained by P. W. Crane of the University of Cincinnati. These figures were compiled from data obtained by Mr. Crane in connection with his work on the molding sands of the district tributary to Cincinnati. The work was part of a Mineral Resource survey made under the auspices of the Cincinnati Chamber of Commerce. It is with their kind permission that the figures are published.

Mr. Crane made a careful record of the uses of all sands which he tested, and from these data a tabulation was made. These are given in Appendix B to this report.

Standard Sand for Testing Sieves

In view of the fact that a dispute sometimes arises over the accuracy of or agreement between two sets of sieves, the committee has thought it desirable to have prepared some samples of standard sand for testing sieves. These samples, which can be obtained from Professor H. L. Campbell of the University of Michigan, represent synthetic ones and are made up each of 10 grams of sand held on the 20, 30, 40, 50, 60, 70, 80, 100, 140 sieves and passing the 140-mesh sieve.

When this standard sample is put through a series of sieves of the numbers mentioned, exactly 10 grams should remain on each of the sieves if they are properly calibrated.

Fineness Test

While this test, on the whole, has been found satisfactory, it has nevertheless been given further consideration by the subcommittee with the view both to finding means for shortening the time of the test and also for considering the different types of shaking apparatus which might be used.

In the original instructions for making the fineness test, it was recommended that in the case of sands containing no clay a 100 gram sample be taken and shaken for 30 minutes. The sub-committee now recommends that the quantity used be reduced to 50 grams and the time of shaking to 15 minutes.

During the past year, several new types of shaking machines have been placed on the market, and the question has arisen how they compare with those previously used. In order to get comparative data on this matter, a series of fineness tests were run on the Rotap,[1] Vibrote,[2] Great Western Shaker[3] and the machine made by the Foundries Supplies Manufacturing Company.[4] These tests were made in part by your chairman and in part by A. A. Grubb. On recommendation of the Sub-Committee on Tests, the results obtained by these experiments are herewith included in the Sub-Committee's report and form Appendix C of this report.

It may be added that the time of shaking for the individual machines was as follows:

Rotap	15 minutes
Great Western	15 minutes
Vibrote	10 minutes
Foundries Supplies Mfg. Co.	5 minutes

Without making any detailed comparison of the four machines tried, it may be said that the results obtained with the different ones are in fairly close agreement.

In an earlier report, attention was called to the fact that instead of using the rotary shaker for disintegrating the sand samples in water with the added amount of alkali, that a milk shake stirrer could be used, and figures were given to show that the proportion of clay obtained from a given sand was much the same whichever type of machine was used for disintegration. The committee now recommends that a milk shake stirrer can be substituted for the revolving shaker, but that the containing vessel be supplied with baffles and that the time of stirring be five minutes.

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[1] Made by the W. S. Tyler Co., Cleveland, O.
[2] Made by the Traylor Vibrator Co., 1430 Delganey St., Denver, Colo.
[3] Made by Great Western Mfg. Co., Leavenworth, Kan.
[4] Made by the Foundries Supplies Mfg. Co., 2221 Orchard St., Chicago, Ill.

The committee also wishes to recommend that the sieves U. S. Bureau of Standards Nos. 30 and 50 be added to the series now used in making the Fineness Test.

Refractoriness Test

Attention has already been called to the need of a Refractoriness Test, and the Committee has received numerous inquiries regarding one.

After giving the matter considerable thought, and also on the basis of much co-operative work done by C. M. Saeger, Jr., of the Bureau of Standards and C. A. Hansen of the General Electric Company, it has been decided to recommend a so-called Sintering Test devised by Mr. Saeger as a tentative standard test for determining the refractoriness of sands.

It will be of interest to know that Mr. Saeger, in connection with his experiments, requested a number of foundries to submit samples of sand mixtures which they had used, and which they had found to exhibit different degrees of refractoriness in foundry practice. These data were then checked with those obtained by him in his own tests and the results showed a rather close agreement. In other words, a series of sands arranged by a given foundry in the order of their refractoriness showed practically the same sequence when judged by the Refractoriness Test.

The details of the test as reported by the Bureau of Standards appear in the revised test pamphlet, which may be obtained through the secretary of the American Foundrymen's Association, 222 W. Adams Street, Chicago.

Core Test

At the 1926 Detroit meeting of the Association there was presented a report on the testing of core mixtures. Two changes are now recommended in this report.* The first is that in preparing the briquette for the tensile strength test, the sand be rammed into the mold by the permeability rammer instead of by hand impact. Three blows of the A. F. A. Permeability Rammer are to be used and the excess of sand above the top of the briquette mold is to be cut off.

*The report of the Sub-Sub-Committee on Core Tests is attached as Appendix D.

In case a multiple core box is used for making the briquettes the ramming is to be done with the Doty Bar Test Rammer, the same being adjusted to give the same compaction to the sand as is given by the Permeability Rammer.

The Committee at the present time not only recommends the Tensile Strength Test of core mixtures as a tentative standard one, but in addition also recommends the inclusion of a Transverse test as a tentative standard method. Description of the latter test is also included in the revised test pamphlet to be published by the A. F. A.

Mold Permeability Testing

It has already been pointed out that by attaching a tube to the A. F. A. Permeability apparatus, the former terminating in a suitable tip, that this tip can be pressed against the surface of a mold in order to get its permeability. The committee recommends that for this purpose a tube of one-half inch diameter be used and that the cup of the permeability tester which attaches the tube to the cork of the A. F. A. permeability apparatus shall be two inches inside diameter and two inches long.

This tip can be used on green sand molds, dry sand molds or baked cores.

The sub-committee which has this under consideration is now developing a penetrating tube, which can be forced into the mold, like a sprue cutter, to be used for determining interior permeability.

Bond Clay Tests

The increasing use of bond clays in sand mixtures has brought to our attention the need of a standard test for evaluating the properties of such materials, and accordingly a sub-sub-committee of the sub-committee on tests was appointed to evaluate the properties of bentonites and other bonding clays. This committee has not yet been able to formulate a report, for the subject is an important one and will involve considerable study as well as laboratory and foundry investigation. It is hoped, however, that it will be able to present some results in the not distant future.

Work Still to Be Done

In closing this report, your chairman wishes to simply list some of the problems which still remain unsolved. They are:

(1) Development of a standard method for testing the hardness of molds.
(2) A rapid and accurate moisture test.
(3) Sand durability test.
(4) A method for shortening the time required to separate the clay from the sand in the fineness test.
(5) A rapid method for determining colloids.
(6) Test for measuring the flow of sand in molds.
(7) Test for sea coal in molding sands.

Respectfully submitted,

H. Ries, *Chairman.*

Appendix A

COMPARISON OF GREEN BOND TEST METHODS

Reported by A. A. Grubb, Ohio Brass Co., Mansfield, O.

The tests recorded below were made, first, to compare the various methods proposed for measuring green bond strength, and second, to investigate the machines available to the writer for making the tests.

The following strength testing machines were available:

Adams Compression Machine
Federal Double Shear Machine
Grubb Tensile Device
Single Shear Machine

The single shear machine was constructed by the writer to apply a shearing stress on the standard permeability specimen. The shearing edges are parallel and $\frac{1}{16}$ inch apart when nearest together as recommended by Dietert. The device is constructed to apply the load under the force of a spring when a crank is turned. The actual load applied was divided by four so the results recorded are in pounds per square inch of fractured surface.

The Federal double shear machine shears the standard permeability specimen along two planes which are roughly parallel with the axis of the specimen. The machine is calibrated in pounds and ounces total load and also with a scale that is said to be comparable with that of the Dietert single shear machine.

Tests were made on each sample at various moisture contents. Samples of widely different types and grades were used.

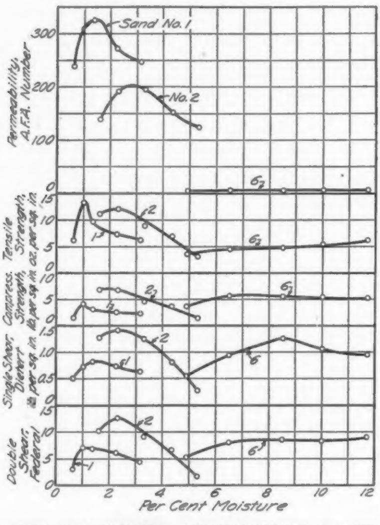

FIG. 1—DATA OF TABLE 2, COMPARISON OF STRENGTH TESTS (GREEN BOND) OF FOUNDRY SANDS

Permeability, dry tensile and dry compression determinations were also made. Each value recorded is the average of at least two determinations, usually three. Three or more determinations were made but in case one varied widely from the others, it was discarded.

The data are given in Tables 2 and 3 and the data for certain sands are shown plotted in Fig. 1.

Table 2

COMPARISON OF STRENGTH TESTS OF FOUNDRY SANDS

Sand No.	Moisture	Green Permeability	Green Tensile	Green Compression	Single Shear	Double Shear	Dry Tensile	Dry Compression
1*	0.61	240	6.1	1.5(?)	0.50(?)	3.0(?)	...	..
1*	1.00	310	13.4	4.1	0.72	7.1	5.0	3
1*	1.37	327	9.8	3.2	0.82	6.8	8.3	28
1*	2.24	273	7.3	2.7	0.73	6.0	16.0	55
1*	3.15	247	6.3	2.4	0.64	4.4	23.0	64
2*	1.60	140	11.2	6.9	1.27	10.1	...	7
2*	2.30	193	12.2	6.8	1.41	12.5	2.6	15
2*	3.30	197	9.0	4.6	1.00	9.1	10.0	25
2*	4.33	152	7.0	3.7	0.80	6.6	12.7	33
2*	5.30	125	3.1	1.5	0.28	1.7	15.0	40
3†	2.38	17.8	13.7	8.2	1.30	10.5	1.9	22
3†	4.07	31.0	10.4	7.0	1.50	12.0	15.7	83
3†	5.44	39.0	9.0	6.5	1.50	10.5	28.3	112
3†	7.30	30.0	8.6	6.0	1.40	10.2	53.0	157
3†	9.66	20.2	8.5	6.0	1.40	10.0	73.0	215
4†	2.03	2.9	6.4	7.0	0.77	9.5	...	10
4†	3.71	9.5	13.1	11.9	1.70	16.5	2.1	24
4†	6.82	11.0	13.6	11.0	1.93	19.6	6.4	40
4†	8.92	14.7	10.1	7.9	1.87	15.0	12.3	59
4†	10.00	7.8	8.8	7.6	1.70	12.5	26.0	75
5‡	4.10	6.5	3.0	3.4	0.43	4.1	...	4
5‡	6.00	6.8	4.0	4.2	0.75	5.8	0.7	8
5‡	7.70	7.4	4.7	4.7	0.95	7.2	2.4	10
5‡	9.70	8.0	5.1	4.6	1.00	8.2	4.4	16
5‡	12.10	7.0	5.5	4.3	0.88	8.0	5.8	20
6‡	4.90	5.7	3.7	3.7	0.55	5.2	...	6
6‡	6.50	6.0	4.7	5.7	0.95	8.0	1.7	10
6‡	8.50	6.5	4.8	5.6	1.26	8.5	4.7	17
6‡	10.00	6.9	5.4	5.5	1.06	8.3	5.9	24
6‡	11.70	6.0	6.2	5.3	0.95	9.0	6.7	35
7	3.10	5.8	6.6	5.9	0.87	8.9	...	10
7	4.50	15.0	7.5	7.1	1.20	10.2	...	14
7	5.80	21.1	8.0	10.0	1.50	11.2	7.0	20
7	7.80	24.0	8.1	8.3	1.52	11.9	9.0	38
7	9.70	20.0	8.6	8.0	1.80	12.7	20.0	65
7	11.96	8.7	9.4	7.1	1.90	12.7	36.0	174
8	3.72	16.0	3.8	9.5	1.30	...	...	..
8	5.30	39.0	7.7	8.9	1.80	11.0	...	13
8	7.30	49.0	10.3	11.8	2.00	15.7	1.0	22
8	9.67	40.0	14.2	10.6	2.40	20.0	3.0	42
8	12.25	17.0	14.3	10.8	3.00	15.9	13.0	98
9	3.72	46.0	3.9	5.7	0.75	8.0	...	9
9	5.53	64.0	5.0	6.1	0.78	9.2	1.0	15
9	7.72	66.0	5.5	5.6	0.92	9.7	5.0	28
9	10.02	56.0	5.5	4.8	1.20	8.5	12.0	40
9	12.25	11.0	4.3	3.5	1.10	6.2	18.0	74

*Synthetic. †Rebonded Refuse Sand. ‡Fine New.

Table 3

COMPARISON OF GREEN BOND TESTS

Moisture Per Cent	Permeability	Grubb Tensile Ounces Per Square Inch	Adams Compression Pounds Per Square Inch	Federal Compression Pounds Per Square Inch	Single Shear Pounds Per Square Inch	Double Shear Pounds Per Square Inch
			Good Brass Sand			
7.5	20.5	4.5	3.10	2.59	0.78	3.56
7.5	20.0	4.8	3.20	2.55	0.97	3.31
7.5	20.0	4.8	3.20	2.65	0.87	3.75
7.5	....	...	....	....	0.79	....
7.5	....	...	....	....	0.73	....
Average	20.2	4.7	3.17	2.60	0.83	3.54
			Medium Brass Sand			
5.55	19.5	4.4	2.90	2.46	0.81	3.81
5.55	21.0	4.4	2.80	2.43	0.63	3.00
5.55	20.0	4.5	2.90	2.27	0.69	3.31
5.55	19.0	...	....	....	0.62	....
5.55	19.5	...	....	....	....	....
5.55	19.5	...	....	....	....	....
Average	19.7	4.43	2.87	2.38	0.69	3.37
			Poor Brass Sand			
5.95	17.0	4.3	3.25	2.51	0.65	3.81
5.95	17.5	4.4	3.20	2.51	0.77	3.06
5.95	17.5	4.3	3.20	2.51	0.69	3.31
5.95	18.0	...	....	....	0.80	....
Average	17.5	4.33	3.22	2.51	0.73	3.37
			Good Malleable Sand			
6.05	22.0	4.4	3.60	2.71	0.67	4.56
6.05	22.0	4.2	3.60	2.63	0.71	4.37
6.05	21.5	4.2	3.40	2.61	0.89	3.75
6.05	....	...	....	....	0.73	5.00
Average	21.8	4.27	3.53	2.65	0.75	4.42
			Medium Malleable Sand			
7.05	27.0	3.5	3.15	2.47	0.57	3.12
7.05	26.5	3.6	3.15	2.45	0.55	2.81
7.05	26.5	3.6	3.15	2.23	0.77	2.50
7.05	....	...	....	....	0.69	3.69
7.05	....	...	....	....	0.64	....
Average	26.7	3.57	3.15	2.38	0.64	3.03
			Poor Malleable Sand			
5.85	35.0	2.8	2.60	1.71	0.61	2.56
5.85	37.0	3.0	2.30	1.71	0.51	2.69
5.85	35.0	3.1	2.70	1.69	0.50	2.81
5.85	36.0	...	....	....	0.53	....
5.85	35.0	...	....	....	....	....
5.85	35.0	...	....	....	....	....
Average	35.5	2.97	2.53	1.70	0.54	2.69

Remarks. No two of the tests yield results that in every case are parallel.

Very open sands yield much higher tensile strength values in proportion to their other strength test values. Compare the curves (Fig. 2) for samples (1), (2) and (6). Tensile shows (1) at its maximum value the strongest, (2) next and (6) weakest. The other tests show (1) the weakest with (2) and (6) about the same, (2) possibly a little stronger.

Compression and shear test frequently show maximum values at slightly lower moisture contents than tensile strength.

Tensile tests frequently increase with moisture up to rather high moisture contents, especially on high clay sands. The other tests usually drop off with these higher moisture values.

Tensile tests show up colloidal clay bonded sands to a better advantage than do the other tests.

The high compression and shear values of sands containing fines are probably due to the "bracing" effect of fine particles lying between the grains.

The double shear test seems to be a combination shear and compression test. I see in it no advantage over the single shear test unless it lies in the ease of application: possibly it is easier to design a double shear device that is free of friction than a single shear machine.

REPORT ON FOUR TYPES OF TESTING MACHINES FOR GREEN SAND CONTROL WORK

Reported by C. P. Randall, Hunt-Spiller Mfg. Corp., Boston

The purpose of this report is to determine whether or not any relation exists in data obtained by testing same sands with the various strength testing machines, and, if possible, to decide which machine is the most satisfactory in all respects. The equipment used for this work includes: the Adams green bond compression machine, which reads directly in pounds per square inch; the Grubb tensile machine, which reads in ounces actual pull applied and can be calculated to ounces per square inch; the Dietert shear testing apparatus, which has a dial that is graduated for compression in tenths up to 17 pounds per square

inch; and a double shear machine loaned by the Federal Foundries Supply Co. which reads in pounds per cubic inch, or in actual pounds resistance offered by the sand specimen.

Description of Apparatus

*Adams Green Bond Compression Machine:** This apparatus has a movable fulcrum which supports a graduated beam that reads directly in pounds per square inch. The weight on one end is fixed in position and as the fulcrum gradually travels away from the weight, the load applied at the opposite end of the beam becomes greater. This pressure, when great enough, crushed the sand specimen which has previously been placed between two circular discs.

*Grubb Tensile Machine:** The core used on this machine is the standard 2 inch core made in a split core box. The box is held together by a thumb screw arrangement and is made loose only when the specimen is ready to test. The core is pulled apart in cross section at a distance of approximately 1 inch from either end of the core. To prevent the specimen from sliding in the tube there are cut out of the brass cylinder on the inside three grooves or notches on both sides of the breaking point. There is attached to the upper half of the cylinder a yoke, and in breaking the specimen a hook is placed on the under side of this yoke. A spring scale is attached to the hook, and a fish cord leads over two pulleys and then to a shaft with a handle for turning. As the shaft revolves the cord winds around it and creates a pulling effect on the scale which in turn delivers this tension to the sand specimen.

*Dietert Shear Testing Machine:** This apparatus uses the standard 2 inch core and shears the specimen through the center. It operates by turning a hand screw which has a piston at the other end. The piston forces oil against a head which is in contact with the sand core. The pressure exerted is read on a dial connected in the system.

*For detailed description of this apparatus see publication *Standard and Tentatively Adopted Methods of Testing Foundry Sands*, American Foundrymen's Association, 1928 edition.

Federal Foundry Shear Testing Machine:† No oil or spring is used in this apparatus. The principle is that of a pendulum, or a weight suspended on an arm. The core is placed in a core block and set on a platform. The pressure is applied by means of a screw in contact with the upper plate of the core block. The force created by the screw is transmitted through the specimen to the platform. This is connected to a square rod which is slotted on one face for a gear. As the rod moves downward from the force of the screw, it causes the pendulum to move upward in a circular motion, thus offering a resistance to the downward pressure. The hand of the dial is connected to the pendulum so that it moves simultaneously with it. The pointer carries a dead hand which remains at the maximum load, when the specimen breaks.

In Table 4 there are listed 99 sands with the values from each machine. For each average two or more cores were broken.

The sands tested and shown in Table 4 were taken from nine different heaps for a period of eleven days and have been grouped in that manner. For example all sand numbers in Group 1 represent the same heap sand taken from the foundry for eleven days.

Group 1—Sand Bonded with Medium Gravel. Sands Nos. 9, 18, 27, 36, 45, 54, 63, 72, 81, 90, 99.

Group 2—Sand Bonded with Revivo. Sands Nos. 1, 10, 19, 28, 37, 46, 55, 64, 73, 82, 91.

Group 3—Sand Bonded with Revivo. Sands Nos. 7, 16, 25, 34, 43, 52, 61, 70, 79, 88, 97.

Group 4—Sand Bonded with Bentonite. Sands Nos. 2, 11, 20, 29, 38, 47, 56, 65, 74, 83, 92.

Group 5—Sand Bonded with Bentonite. Sands Nos. 3, 12, 21, 30, 39, 48, 57, 66, 75, 84, 93.

Group 6—Sand Bonded with Bentonite. Sands Nos. 4, 13, 22, 31, 40, 49, 58, 67, 76, 85, 94.

Group 7—Sand Bonded with Bentonite. Sands Nos. 5, 14, 23, 32, 41, 50, 59, 68, 77, 86, 95.

†Federal Foundry Supply Co., Cleveland, O.

Table 4

Sand No.	Cornell Compression Average Lbs. per Sq. In.	Dietert Shear Average	Grubb Tensile Average Oz. per Sq. In.	Federal Foundry Shear Average Lbs. per Cu. In.
1	9.70	12.25	8.10	1.90
2	8.00	7.70	8.10	1.75
3	9.13	9.55	8.75	1.85
4	10.16	10.60	10.35	1.95
5	10.73	12.20	10.35	2.20
6	7.13	9.30	10.65	1.65
7	5.70	6.25	4.95	1.10
8	11.53	10.95	12.60	2.10
9	8.43	9.30	10.65	1.60
10	9.26	9.55	8.10	1.95
11	8.90	8.30	8.10	1.70
12	10.00	11.50	10.00	2.10
13	10.00	12.10	10.95	2.50
14	10.30	9.20	10.35	2.15
15	6.86	8.95	11.30	1.90
16	5.36	6.75	4.95	1.10
17	11.00	11.60	11.30	2.30
18	9.76	8.40	9.40	1.95
19	10.26	10.15	9.05	2.00
20	10.00	11.20	10.95	2.15
21	10.66	10.60	11.30	2.35
22	10.50	11.80	11.60	2.40
23	9.70	9.75	8.90	2.15
24	7.13	9.90	10.35	1.80
25	5.53	5.95	4.95	1.00
26	12.76	15.75	14.50	2.90
27	9.80	10.40	10.00	2.00
28	9.63	10.60	7.95	1.80
29	10.60	11.50	9.55	2.10
30	10.97	12.90	10.95	2.10
31	8.00	8.25	7.00	1.65
32	10.30	9.85	9.70	2.05
33	7.63	8.40	10.00	1.85
34	5.70	6.60	4.45	1.05
35	12.70	12.50	13.00	2.15
36	9.87	8.65	9.55	2.00
37	10.23	9.35	8.10	1.90
38	10.30	11.90	9.55	2.10
39	11.13	12.60	10.65	2.20
40	8.37	8.25	7.55	1.65
41	10.40	10.20	9.25	2.10
42	7.27	7.75	8.90	1.70
43	6.43	5.40	4.45	1.05
44	14.73	15.20	14.39	2.65
45	9.73	8.80	7.30	1.80
46	10.30	11.50	8.90	2.10
47	11.10	12.00	10.00	2.20
48	11.27	12.10	10.20	2.45
49	8.97	9.60	7.55	1.80
50	11.47	12.10	9.55	2.10
51	7.43	9.25	9.85	1.70
52	6.23	6.60	4.30	1.10
53	13.67	15.25	15.10	2.75
54	10.00	10.06	9.05	1.80
55	10.43	11.30	7.95	1.90

(Table 4 continued on next page)

Table 4

(Continued)

Sand No.	Cornell Compression Average Lbs. per Sq. In.	Dietert Shear Average	Grubb Tensile Average Oz. per Sq. In.	Federal Foundry Shear Average Lbs. per Cu. In.
56	12.03	14.40	11.15	2.15
57	11.97	13.15	12.10	2.50
58	10.17	9.30	8.10	1.95
59	11.57	12.95	11.60	2.20
60	7.90	9.85	11.15	1.60
61	6.13	6.45	4.60	1.00
62	13.00	14.90	12.73	2.50
63	9.77	9.35	9.40	1.75
64	10.70	11.70	8.10	1.90
65	12.83	13.15	10.65	2.50
66	12.77	12.55	12.30	2.55
67	10.70	10.80	8.90	2.05
68	11.13	12.80	10.00	2.25
69	6.97	9.35	8.90	1.60
70	6.63	6.55	4.45	1.00
71	13.27	15.70	14.15	2.55
72	10.97	11.35	8.75	2.00
73	10.17	10.65	7.55	1.80
74	11.67	11.90	10.00	2.55
75	11.73	11.95	10.80	2.50
76	11.03	12.55	9.85	2.35
77	11.50	11.40	11.15	2.45
78	6.57	8.60	9.05	1.50
79	7.03	6.65	4.60	1.05
80	14.47	15.00	15.40	3.00
81	10.87	11.65	9.25	2.15
82	9.97	9.70	7.15	1.75
83	11.27	12.70	9.70	2.50
84	10.93	10.60	9.55	2.30
85	10.47	10.55	9.55	2.30
86	11.20	12.30	10.00	2.35
87	8.80	10.30	11.15	2.15
88	7.77	7.10	5.10	1.30
89	15.80	14.00	17.00	3.05
90	10.97	9.75	10.50	2.05
91	10.87	9.90	7.45	2.10
92	12.13	11.40	10.65	2.45
93	11.93	13.50	9.70	2.50
94	11.07	11.80	9.05	2.20
95	11.43	13.00	9.85	2.45
96	7.95	9.10	10.20	1.80
97	7.97	7.30	4.75	1.35
98	15.70	15.25	16.05	3.00
99	11.27	10.30	9.05	2.45

Group 8—Sand Bonded with Bentonite. Sands Nos. 6, 15, 24, 33, 42, 51, 60, 69, 78, 87, 96.

Group 9—Sand Bonded with Bentonite. Sands Nos. 8, 17, 26, 35, 44, 53, 62, 71, 80, 89, 98.

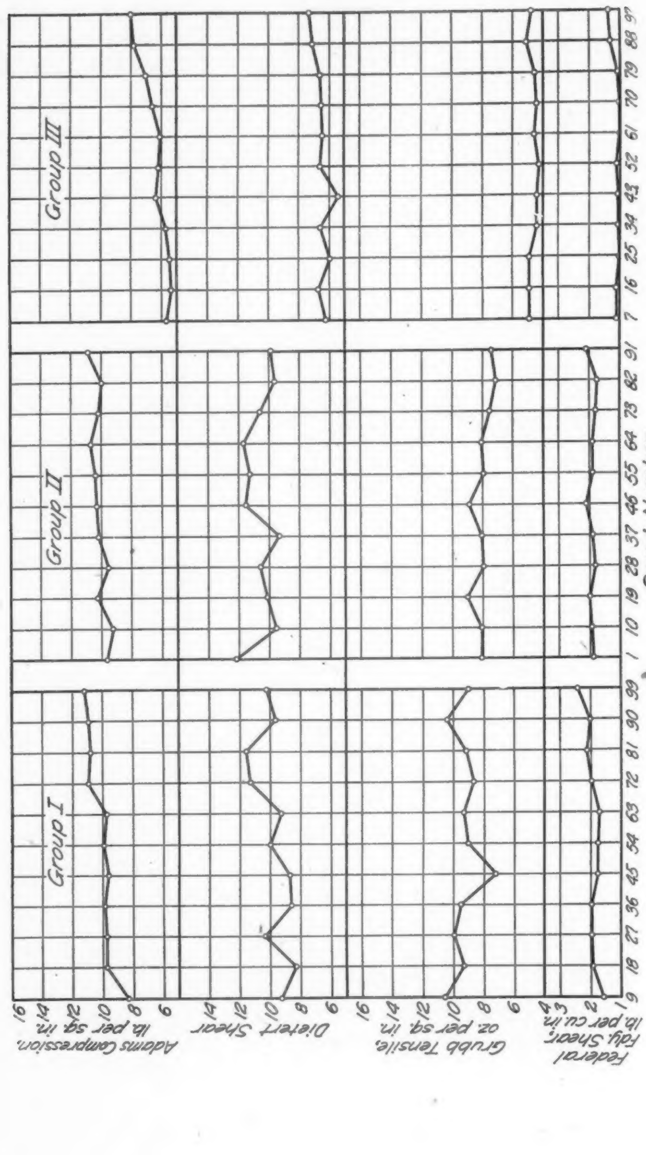

FIG. 2A—COMPARISON OF STRENGTH TESTS OF SANDS OF TABLE 4

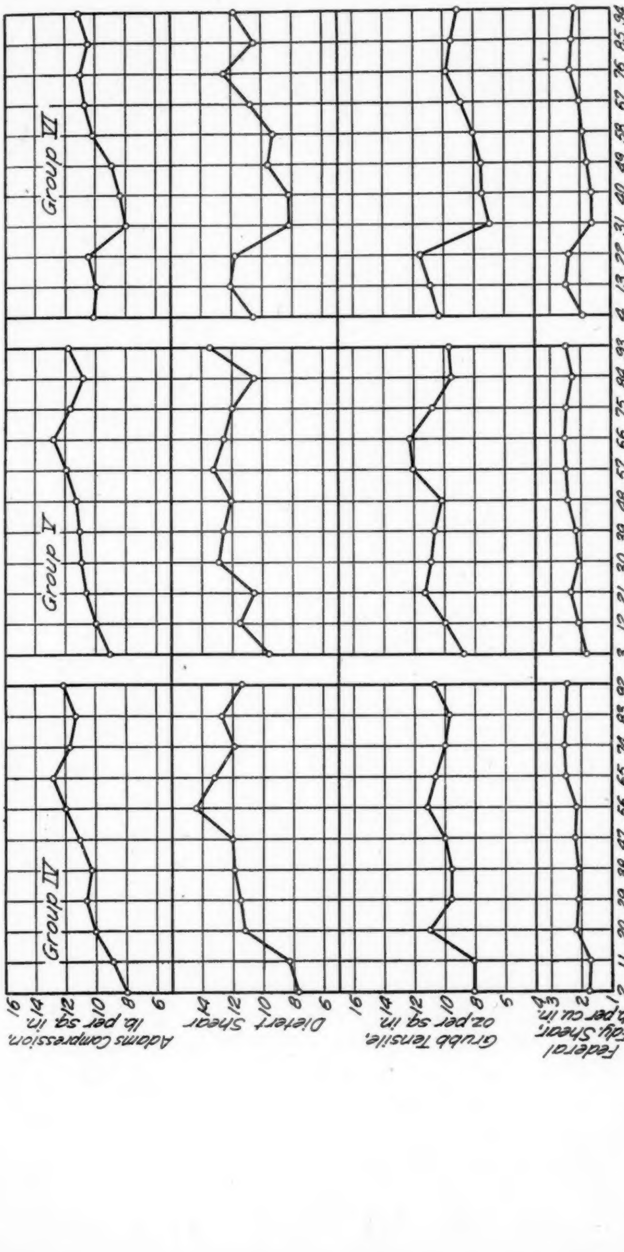

FIG. 2B—COMPARISON OF STRENGTH TESTS OF SANDS OF TABLE 4

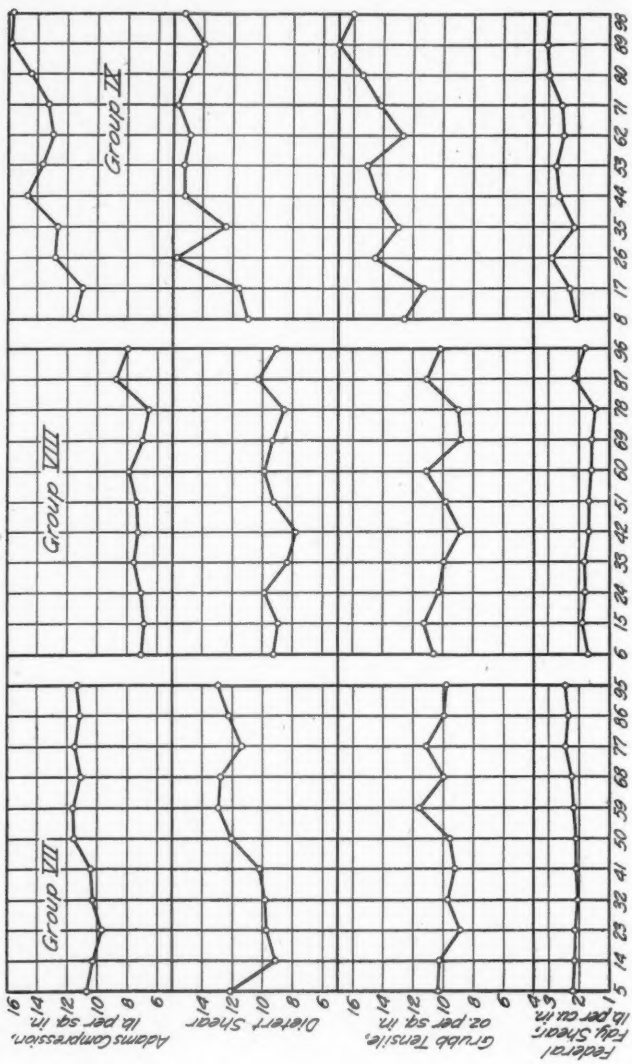

FIG. 2C—COMPARISON OF STRENGTH TESTS OF SANDS OF TABLE 4

The curves of Figs. 2A, B and C have been drawn by groups, as it was believed that by plotting figures from the four machines on the same sand over a period of eleven days, a better idea of which machine or machines would give the most consistent results, would be obtained.

A time study was made on each apparatus. This factor is very necessary in sand control work where many samples are taken throughout the day and tested for strength. On each machine the time taken was from the point where the sand was put into the brass cylinder until the specimen had been broken and the machine made ready for another test. At least three tests were made on each machine.

Table 5

	Minutes	Seconds	Average Min.	Average Sec.
Adams Compression				
Test No. 1	1	26		
Test No. 2	1	32		
Test No. 3	1	18	1	23
Test No. 4	1	18		
Dietert Shear				
Test No. 1	..	38		
Test No. 2	..	38	..	39
Test No. 3	..	40		
Grubb Tensile				
Test No. 1	..	52		
Test No. 2	..	48		
Test No. 3	..	51	..	51
Test No. 4	..	54		
Federal Foundry Shear				
Test No. 1	..	29		
Test No. 2	..	31	..	31
Test No. 3	..	32		

It is obvious in Table 5 that the Federal Foundry Shear test takes the least time to run. The reason for this is no doubt the fact the machine automatically adjusts itself to the zero position. In the case of the Dietert Shear and Adams Compression considerable time is lost in turning back the screw to its normal position. With the Tensile apparatus, however, the time is lost in pushing

the sand out of the brass tube and in fitting the latter together for the next test.

Study of Curves

It will be noticed that no unit of strength is included in the curves Figs. 2A, B and C for the Dietert Shear test. This was omitted because the gauge connected to the machine reads in pounds per square inch for compression. Although the whole core

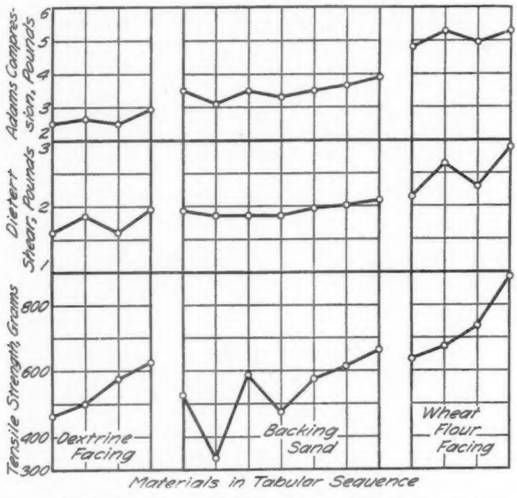

FIG. 3—COMPARISON OF GREEN BOND TESTING APPARATUS DATA OF TABLE 6 (COMPILED BY A. C. JONES)

is under slight compression during the test the rupture of the specimen takes place through the center and not over the entire core.

It is difficult to single out any one piece of apparatus by a study of the curves. The only criterion that bears weight in the selection of one of the four machines is the tendency of the curves to parallel one another. By following the four curves in each group it will be noted that the Federal Foundry Shear and the Adams Compression and Grubb Tensile are most uniform in practically every group. The Dietert Shear appears to have quite erratic points throughout the nine groups. However, this condi-

tion exists in our own particular types of sands and may or may not have the same relation in some other class of sands. Inasmuch as these machines do not have the same units of measure, and because of the method employed in destroying the specimen it would be unwise to state definitely that one machine is better suited for sand testing than the other. For example it has been stated that the tensile machine is more sensitive than the compression machine to sands bonded with Bentonite. It is due then, to the inherent quality of the sand that the individual should select the type machine best suited for his class of work.

Conclusion

It may be stated then, that the type of testing machine most applicable to sand testing depends partly on the sand to be tested and partly on the time allowed for testing. Any one strength test is comparative from day to day so to select one does not mean that the others are worthless. If, however, a real study of the sand is to be made, the compression test will answer best.

Table 6

COMPARISON OF GREEN BOND TESTING APPARATUS — TESTS BY A. C. JONES, LEBANON STEEL FOUNDRY

Material Used	Moisture, Per Cent	Perme-ability	Grams Strength per 2 Sq. In., A. F. A. Standard Cohesiveness			Pounds Strength Deitert Shear			Pounds Strength Adams Compression			Grams Strength Tensile		
			1	2	Avge.	1	2	Avge.	1	2	Avge.	1	2	Avge.
Dextrine facing	2.5	167	142	144	143	1.6	1.6	1.6	2.6	2.4	2.5	450	475	463
Dextrine facing	2.0	173	130	140	135	1.7	1.8	1.85	2.7	2.6	2.65	475	525	500
Dextrine facing	1.7	193	133	136	134.5	1.6	1.6	1.6	2.4	2.6	2.5	550	600	575
Dextrine facing	2.0	198	137	131	134	1.9	2.0	1.95	3.0	2.9	2.95	600	650	625
Backing sand	3.7	163	146	152	149	1.9	1.95	1.93	3.4	3.6	3.5	500	550	525
Backing sand	3.6	167	144	148	146	1.85	1.85	1.85	3.0	3.2	3.1	325	350	338
Backing sand	3.8	142	148	146	147	1.8	1.9	1.85	3.4	3.6	3.5	600	575	588
Backing sand	3.5	156	144	147	145.5	1.8	1.9	1.85	3.4	3.2	3.3	450	500	475
Backing sand	3.5	146	152	150	151	1.9	2.0	1.95	3.4	3.6	3.5	550	600	575
Backing sand	3.0	151	154	150	152	1.9	2.1	2.0	3.6	3.7	3.65	625	600	613
Backing sand	2.7	173	157	159	158	2.1	2.1	2.1	3.9	3.9	3.9	650	675	663
Wheat flour facing	4.4	126	173	165	169	2.1	2.2	2.15	4.7	4.9	4.8	625	650	637
Wheat flour facing	4.7	126	183	187	185	2.8	2.5	2.65	5.2	5.4	5.3	700	650	675
Wheat flour facing	4.0	122	172	178	175	2.4	2.2	2.3	4.8	5.1	4.95	725	750	737
Wheat flour facing	4.2	138	178	180	178	2.7	2.9	2.9	5.3	5.3	5.3	875	900	888

DATA PLOTTED AS FIG. 3, PAGE 730

Table 7

COMPARISON OF RESULTS OBTAINED WITH TRANSVERSE AND TENSILE TESTS BY H. L. CAMPBELL, UNIVERSITY OF MICHIGAN

Core Sand Mixtures

Mixture Used	Transverse Test: Breaking Loads	Transverse Test: Maximum Variation, Per Cent	Tensile Test: Breaking Loads	Tensile Test: Maximum Variation, Per Cent
Mich. City Sand 40-50	38		190	
Raw Linseed Oil, 1 to 50 vol.	37		182	
Water, 8% by volume	37		185	
Baked 1 hour at 425° F.	37		205	
Average	37	3	190	8
Mich. City Sand 50-60	44		231	
Raw Linseed Oil, 1 to 50 vol.	44		210	
Water, 8% by volume	44		233	
Baked 1 hour at 425°F.	43		224	
Average	44	2	225	7
Mich. City Sand 60-70	47		257	
Raw Linseed Oil, 1 to 50 vol	48		205	
Water, 8% by volume	48		210	
Baked 1 hour at 425°F.	47		243	
Average	47	2	229	12
Mich. City Sand 70-80	51		220	
Raw Linseed Oil, 1 to 50 vol	51		235	
Water, 8% by volume	51		224	
Baked 1 hour at 425°F.	50		242	
Average	51	2	230	5
Ottawa Silica 40-50	46		235	
Raw Linseed Oil, 1 to 50 vol.	48		255	
Water, 8% by volume	48		240	
Baked 1 hour at 425°F.	49		245	
Average	48	4	244	5
Ottawa Silica 50-60	55		252	
Raw Linseed Oil, 1 to 50 vol	53		255	
Water, 8% by volume	55		265	
Baked 1 hour at 425°F.	55		280	
Average	55	4	263	7
Ottawa Silica 60-70	52		234	
Raw Linseed Oil, 1 to 50 vol.	51		253	
Water, 8% by volume	51		238	
Baked 1 hour, 15 min. at 425°F.	52		260	
Average	52	2	246	6

Appendix B

SANDS USED FOR DIFFERENT CLASSES OF WORK*

By P. W. Crane,† Cincinnati, O.

Since the use to which a molding sand may be put depends entirely upon its physical properties, and since reliable tests have been developed for measuring these physical properties, it should be possible to establish specifications for sands to be used for specific types of castings, in terms of the test figures. These specifications would involve certain limits of fineness, permeability, and strength, found by experience to give the best results for each type of casting.

In the past, the successful selection of a sand for a particular class of work depended entirely upon the experience and skill of the foundryman. The appearance of the sand and its feel, and finally its actual success in the heaps, were the only means available for judging its merits. Often the judgment of two foundry superintendents would differ widely concerning a sand to be used for a particular job.

The Survey Laboratory was interested in learning for what purposes local sands were being successfully used: also whether any similarity existed between the sands used by different foundries making the same class of work. The theory of the Laboratory was that there must be a sand which will give the best results for each type of work, and that it might be possible to determine the approximate characteristics of such a sand by testing the heaps of a number of leading foundries and comparing results. Such comparisons, it was thought, would soon show whether or not the setting up of sand specifications, for various classes of work, was feasible.

Accordingly, as much test data on foundry heaps as possible was obtained, chiefly by testing actual heap sands. Other test data was secured from foundries, and producers, and through the courtesy of the American Malleable Castings Association.

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†University of Cincinnati.

It was quite evident, even at first, that different types of foundry practice would have a certain amount of influence upon the kind of sand used, even on identical types of castings. An effort was therefore made to obtain as much information as possible concerning methods of treating the sand, type of ramming, amount of core sand going into heap, use of facing, addition of sea coal, pitch, or other material, and the use of blacking. Most of this information was obtained by correspondence and was far from satisfactory, except in a very few cases. Many of the foundries either did not care to release the data, or were indifferent or not interested. Also, since both time and funds were limited it was not possible to make a thorough study of this problem. Insufficient information was obtained to warrant anything but very general conclusions.

In the discussion which follows, the test results have been separated into several broad classifications, such as "Light Gray Iron," and in some cases these have been divided into more specific classes, as "Stove Plate," for instance. If more data had been available, it would have been far better to further classify each section according to molding methods.

Light Gray Iron

The figures for light gray iron heaps are given in Table 8. The light jobbing heaps show extreme variations in all properties; permeability from 6 to 48, fineness from 85 to 275, strength from 129 to 246, and bonding substance from 4 to 22. The permeability of the majority of the heaps is between 10 and 15, the fineness between 150 and 210, and the strength range is 135 to 170. The two lowest permeability sands are used for special work as piston rings and small hardware castings. The heap with a fineness factor of 86 and 48 permeability is used for light machinery parts and is the same sand used for four ton bed plates, an example of bad foundry practice. The heavy castings blow even when the vent wire is very liberally applied and the small castings have an exceedingly poor surface.

The stove plate heaps, as might be expected, show much less variation than the jobbing heaps. Heap 20 was somewhat coarser than the others but the permeability was no higher, due

to an excessive amount of bonding material. The finish on the castings coming from this heap was not nearly so good as the finish on the castings from the other heaps tested. The limited data would seem to indicate that excellent stove plate can be made in a sand having the following characteristics: Fineness factor, 180-230; permeability, 10-15; bonding strength, 140-180; bonding material, 6-14. Probably the best plate work was made in heaps 22 and 19. Although entirely different sands were used by the two foundries, yet the similarity of the heap characteristics is very striking.

The sands used for hot air furnace castings were, as might be expected, somewhat coarser than the best stove plate sands. The variation in characteristics was in many cases fairly large. Permeability varied from 11 to 48, fineness from 85 to 234, strength from 130 to 195, and bond content from 8 to 22. Very good castings were made in heaps 30, 31, and 34. According to these and some of the other test figures, limits for furnace heap characteristics might be established as follows: Permeability, 15-25; fineness, 140-190; bonding substance, 8-15; strength, 140-180.

Medium Gray Iron

The test figures of eighteen foundry heaps used for medium gray iron appear in Table 9. No attempt has been made to further classify the castings according to types, as an insufficient number of heaps were tested to make this worth while. The average permeability for the group is 40 and a good range for the medium work is probably 30 to 50. For heavily rammed molds such as those made with a sand-slinger the upper limit would be somewhat higher, say, 70. The average strength is about 170 and a range of 150-190 seems reasonable for medium work. The fineness factors for the majority of the heaps lie between 90 and 140. The average range of bonding substance is 10 to 18.

Heavy Gray Iron

The test results for heavy gray iron heaps appear in Table 10. The average fineness of all the sands is a little over 70. The maximum range of fineness is from 47 to 128, and the average

Table 8

LIGHT GRAY IRON

	Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1	Light jobbing	41	121	9	8	15	152
2	Light jobbing	62	207	12	7	11	158
3	Light jobbing	41	135	7	8	15	138
4	Light jobbing	52	179	11	8	11	136
5	Light jobbing	51	168	6	6	15	148
6	Very light jobbing	84	262	20	7	6	181
7	Light jobbing	22	86	14	6	48	170
8	Light jobbing	52	160	13	8	16	152
9	Light jobbing	71	210	4	8	28	129
10	Light jobbing	71	201	6	6	15	138
11	Light jobbing	41	140	9	7	26	131
12	Light machinery parts	62	207	14	6	12	161
13	Small valve castings	51	175	11	7	10	171
14	Light valve castings	41	141	8	8	31	129
15	Plow points	52	172	14	9	25	181
16	Bench work	64	208	20	6	9	241
17	Light hardware	92	292	13	6	6	246
18	Piston rings	81	260	11	9	6	164
19	Stove plate	62	197	12	9	10	159
20	Stove plate	33	112	18	8	13	173
21	Stove plate	53	156	15	6	16	170
22	Stove plate	73	220	15	6	11	136
23	Stove plate	62	205	14	7	12	160
24	Stove plate	73	230	17	7	7	181
25	Stove plate	41	126	9	6	30	161
26	Furnace castings	72	234	12	7	13	160
27	Furnaces	64	203	22	10	12	195
28	Furnaces	22	86	12	6	48	179
29	Furnaces	62	197	14	8	15	174
30	Furnaces	51	161	9	7	20	145
31	Furnace jackets	42	142	10	10	15	147
32	Furnace fronts	53	169	18	9	11	145
33	Furnace castings	42	137	10	10	27	162
34	Furnace castings	51	169	8	6	20	160
35	Furnaces	21	85	8	6	43	130
36	Furnaces	42	145	12	7	18	160

Table 9

MEDIUM GRAY IRON

	Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1	Jobbing	43	130	18	6	26	183
2	Jobbing	43	127	15	7	33	201
3	Jobbing	34	96	23	10	61	210
4	Jobbing	31	103	9	7	45	138
5	Jobbing	23	86	15	6	81	173
6	Hot water boilers	35	76	25	8	28	191
7	Boiler grates	42	126	14	6	31	221
8	Boiler castings	34	117	20	9	40	187
9	Boiler castings	..	...	17	7	38	171
10	Boiler castings	32	91	12	6	46	157
11	Medium machinery, sand-slinger	32	111	11	6	49	161
12	Auto cylinders, sand-slinger	22	86	12	8	71	134
13	Auto castings	44	136	20	8	28	191
14	Sanitary ware	31	94	7	8	40	150
15	Valve castings	41	137	8	9	26	135
16	Radiators	43	131	18	9	29	192
17	Radiators	32	112	12	7	21	155
18	Radiators	42	137	10	8	27	180

range is from 60 to 90. The extremes of permeability are 39 and 276 and the average is 100. Excellent heavy castings of the lighter type such as car wheels, and ordinary machinery casting, may be made in sand having a permeability as low as 60 without a great deal of artificial venting. The large bed plates, flywheels, and large engine castings should have permeabilities in the neighborhood of 100. Permeabilities over 150 often indicate an unnecessarily coarse sand, usually a gravel. In most cases such a high permeability provides far more than the necessary venting, at the cost of a poor surface. In comparing the results for the various heap sands it should be remembered that the values are not those of the actual molds due to a difference in ramming and that the sandslinger sand 5 which has a test permeability of 137 may only have an actual permeability of 85 in the mold. Likewise 7, which is used for bond rammed molds may have a permeability not very much below 60.

Sand grains finer than those retained on the 140 sieve, especially the 270 and minus 270 sizes, tend to fill up the spaces between the larger grains of a coarse sand and very much reduce permeability. Even a relatively small amount of the minus 270 size, say 6 per cent, may in some sands cause a marked reduction in permeability, especially where the mold is rammed hard. Consequently, sands which are used for heavy work should contain a minimum amount of this fine material. The strength needed for heavy work, like permeability, depends upon the method of ramming employed. For sandslinger molds the strength may be as low as 130, while a number of the heaps tested had strength figures well above 200. A good average range for ordinary conditions is probably 160-225. The bonding substance runs fairly high except for one or two sands. Limits of 15-25 should be safe.

Light to Medium Malleable

The characteristics of twenty-five heap sands used for light to medium malleable castings are given in Table 11. The extreme values for this group are 6 and 56 for permeability, 118 and 180 for strength, and 130 and 180 for fineness. Heaps 4 and 9 gave particularly good results for light castings. Heap 23 made excel-

Table 10

HEAVY GRAY IRON

	Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1	Heavy jobbing	25	78	29	7	51	185
2	Heavy structural castings and mach. tool cast.	24	67	20	10	147	221
3	Heavy machinery	23	87	19	8	48	195
4	Heavy machinery	13	53	18	8	110	215
5	Heavy machinery, sand-slinger	22	61	13	9	137	132
6	Heavy machine tool castings	23	60	16	7	61	251
7	Heavy mach. tool cast.	13	52	17	8	60	172
8	Heavy machinery	24	74	21	9	96	191
9	Bed plates, dry sand	24	81	20	8	49	210
10	Heavy engine castings, dry sands	23	72	15	9	150	188
11	Gas engine beds	12	47	11	8	162	163
12	Flywheel and gas engine cylinders and beds	25	70	26	10	171	247
13	Gas engine castings	23	70	16	6	135	226
14	Heavy car wheels	32	95	10	8	60	115
15	Carwheels	23	86	15	8	64	163
16	Acid eggs, 3 ton	43	128	16	7	39	176
17	Very heavy work	13	49	19	8	270	212
18	Pipe molds	23	84	18	6	53	172
19	Pump cylinders	23	70	16	6	135	225

Table 11

LIGHT TO MEDIUM MALLEABLE

	Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1	Facing for light cast'g	62	200	12	8	11	160
2	Light jobbing	63	209	16	6	10	215
3	Light jobbing	42	128	11	6	17	161
4	Light jobbing	61	189	9	6	18	143
5	Bench work	32	115	12	6	23	180
6	Bench work	32	90	14	8	56	156
7	Bench work	31	99	9	8	35	118
8	Light bench work	91	292	6	7	6	141
9	Castings below 35 lbs.	42	129	10	7	32	126
10	Light squeezer heap	41	121	8	6	43	139
11	Light squeezer heap	31	118	9	6	35	144
12	Pipe fittings	54	159	24	6	10	170
13	Pipe fittings	41	131	9	8	31	149
14	Hardware	42	138	10	8	14	137
15	Brake wheels	42	138	12	6	19	171
16	Agricultural castings	62	191	10	7	14	150
17	Light to medium jobbing	51	150	8	6	29	137
18	Medium jobbing	43	124	16	9	36	172
19	Medium castings	32	109	10	8	30	153
20	Medium work	42	136	11	6	23	165
21	Medium castings	31	111	7	8	40	129
22	Medium work	41	133	9	6	27	140
23	Medium bench work	32	111	11	6	49	160
24	Medium bench work	22	82	14	8	36	135
25	Railway castings, sand-slinger	31	95	7	7	33	120

lent medium castings. Tentative limits for the physical properties of sands to be used for light malleable work are suggested as follows: Permeability, 15-30; strength, 125-160; fineness, 130-180; bonding substance, 6-15. For medium work: Permeability, 30-50; strength, 125-160; fineness, 90-130; bonding substance, 8-15.

Heavy Malleable

The test figures for fourteen heavy malleable heaps are given in Table 12. Omitting extreme values, approximate limits for heavy malleable work seem to be: Permeability, 40-90; strength, 130-180; fineness, 70-110; bonding substance, 8-15. The fineness curves show a rather striking similarity between the textures of the various sands represented. Taking all physical properties into consideration, however, the sands listed are far from uniform and illustrate very well the great lack of standardization which exists among foundries.

Table 12

HEAVY MALLEABLE

Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1 Heavy jobbing	42	136	13	6	27	190
2 Heavy jobbing	23	86	15	6	81	180
3 Heavy castings	34	112	22	7	46	201
4 Floor molding	32	104	11	6	44	150
5 Heavy floor work	21	60	6	6	125	125
6 Floor work	31	90	6	6	70	120
7 Floor work	28	83	16	8	76	163
8 Heavy bench work	31	69	8	6	76	137
9 Heavy bench work	22	76	12	8	30	142
10 Heavy bench work	21	82	7	6	70	127
11 Railway castings	14	54	20	9	95	192
12 R. R. castings, sandslinger	22	76	12	6	53	124
13 Railway castings	31	119	7	8	43	142
14 Agricultural machinery	31	96	7	8	57	138

Light to Medium Brass

The results for nineteen brass foundry heaps appear in Table 13. The average values for the group are: Permeability, 11; strength, 170; fineness, 217, and bonding substance, 12. Sands Nos. 10 and 11 were obtained from very progressive foundries which are known for their good castings. The permeabilities of these sands are the highest in the group and are considerably higher than the average. A glance at the figures of these sands, for bond content and fineness, reveals the fact that the high permeability is not obtained by using a coarse sand, but by

employing a minimum amount of bonding material. The strength is lower than that of other sands, but both foundries reported no trouble due to washing, or other signs of weakness. The surface of the castings was excellent. Limits for this class of work might be fixed as follows: Permeability, 10-25; strength, 130-170; fineness, 190-240, and bonding substance, 7-12. The fineness curves show considerable variations in grain size distribution. The very fine sand 18, was used in combination with plumbago as a facing for ornamental castings and tablets. A heavy sand was used as a backing. This, to the writer's knowledge, is the only sand in the entire list used strictly as a facing.

Table 13

LIGHT TO MEDIUM BRASS

Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1 Light jobbing	64	196	24	9	9	210
2 Light jobbing	81	263	8	9	12	144
3 Light jobbing	91	280	9	6	5	164
4 Light jobbing	71	239	7	7	5	141
5 Light and medium jobbing	62	181	12	8	12	202
6 Light and medium jobbing	71	234	7	7	10	181
7 Light and medium jobbing	95	276	25	8	5	164
8 Light and medium jobbing	62	188	13	9	8	170
9 Valve castings	72	215	11	9	8	175
10 Valve castings and jobbing	61	191	7	6	23	140
11 Valve castings	61	209	9	10	22	132
12 Machine tool bushings, valves	64	204	20	7	6	160
13 Bronze locomotive and journal bearings	73	217	17	8	13	183
14 Journal bearings	44	145	20	9	22	183
15 Bronze tablets	62	189	14	9	8	176
16 Ornamental castings	62	191	12	6	15	191
17 Ornamental castings	62	203	11	8	14	161
18 Ornamental castings	92	291	13	6	6	221
19 Ornamental castings	62	224	14	7	14	138

Heavy Brass

Only three sands used for heavy bronze castings were tested by the laboratory. The figures for these appear in Table 14. No attempt is made to fix limits for this type of work because of the small number of samples tested.

Table 14

HEAVY BRASS

Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1 Marine castings	31	103	6	8	38	135
2 Pump castings	34	94	20	7	80	191
3 Machinery castings	42	128	10	7	36	142

Aluminum

The test figures for a number of aluminum sands are given in Table 15. Nearly all of them are very fine and have fairly low permeability values. The strength figures are high, probably due to the fact that most of the fine sands are naturally high in bond content, and also that the low temperature at which the metal is poured does not cause a rapid deterioration of the sand. The extreme values of the various properties are: Permeability, 4 and 18; strength, 140 and 195; fineness, 136 and 294; bond content, 7 and 34. The writer is only familiar with the castings made in three of these heaps, Nos. 6, 9, and 11. Of these the ones from the finest heap were the best in appearance. Those from heap 11, the coarsest one, also had an excellent surface, for which the high bond content was probably largely responsible. The limits suggested for aluminum sands are: Permeability, 5-15; strength, 130-170; fineness, 180-190; bonding substance, 8-25.

Table 15

ALUMINUM

	Type of Work:	R. S. Grade No.	A. F. A. Fineness Factor	Bonding Substance, Per Cent	Moisture, Per Cent	Permeability, A. F. A.	Strength, A. F. A. Bar Method
1	Jobbing	71	234	7	9	10	176
2	Jobbing	96	280	34	8	4	175
3	Jobbing	92	294	14	7	4	166
4	Jobbing	94	290	24	8	4	181
5	Jobbing	65	208	25	8	12	193
6	Jobbing	62	188	13	8	8	168
7	Electric motor shells	81	263	8	9	12	140
8	Machinery parts	62	191	12	9	18	185
9	Small castings	91	280	9	6	7	186
10	Automotive castings	92	279	11	9	6	161
11	Automobile castings	44	145	24	10	9	164
12	Small auto. castings	84	265	24	8	4	181
13	Cast. for elec. work	44	136	22	8	6	195

Discussion

In general the best results show a broad variation in the sands used by the different foundries for similar types of work. The differences are due to several factors such as difference in foundry practice, utilization of nearest source of supply, and judgment of the individual foundryman. In some cases, however, there is a marked similarity between the heaps of different foundries and usually these foundries are the ones making very good castings.

An interesting fact brought out by the test figures of the heap sands, is that many foundries are using sands much higher in bond content than is necessary for a safe strength. The sands are usually lower in permeability than other heaps used for the same purpose, or the permeability is maintained by using a coarse texture. The wiser foundrymen use just enough bonding material to maintain sufficient strength to prevent trouble, and can use a sand of finer grain size than their competitors, without lowering the permeability. In fact, in most cases, the permeability is higher than the average permeability of the heaps used for a similar purpose. Thus, a better surface is obtained on the castings and losses due to blows are even diminished.

The limits which have been suggested for the various classes of work are in some cases so broad that they mean very little. In fixing these limits the average range of the heap test figures was considered, and the individual sands from foundries known by the writer to be turning out especially good work were particularly used as guides. In some cases the natural properties of the sand were considered, when the limits were being fixed. Take aluminum, for instance, the upper limit of bond content was set as 25 because the majority of the very fine sands from Ohio, Indiana, and Kentucky and elsewhere, occur with high percentages of bonding material. The limits and extreme values, for all classes of work considered, appear in condensed form in Table 16.

The limits should not be considered as specifications, due to the meager amount of information used in establishing them. On the other hand, they are more than mere guesses, because they are based on actual data. It will probably be a long time before any definite sand specifications will be fixed for different types of castings. Such a condition can only be reached after considerable research into the standardization of molding methods, and after many more foundries have adopted sand control test procedures. Meanwhile, the best method of attack seems to be that of testing the heap sands of those foundries known to produce excellent castings, and who use progressive molding methods. The castings should be classified according to type, and each classification subdivided according to molding methods. The free interchange of information between foundries using sand

control will probably be the greatest factor in the development of sand specifications. Increased standardization of molding methods is inevitable, and with it will come sand specifications, and a widespread adoption of scientific sand control.

Table 16

SUGGESTED LIMITS OF THE PHYSICAL PROPERTIES OF SANDS USED FOR VARIOUS CLASSES OF WORK

	Number of Heaps Considered	Permeability, A. F. A.	Bonding Strength, A. F. A. Bar Method	A. F. A. Fineness Factor	Bond Substance, Per Cent
Light Gray Iron					
General light jobbing	18				
Limits		10–20	130–170	150–210	6–14
Extreme values		6–48	129–246	85–262	4–20
Very good results (Squeezer)		15	138	201	6.6
Stove plate	6				
Limits		10–15	130–170	180–230	6–14
Extreme values		7–16	136–181	112–230	9–18
Very good results		12	160	205	14
Furnace castings	11				
Limits		15–25	140–180	140–190	8–15
Extreme values		11–48	130–195	85–234	8–22
Very good results (floor mold.)		20	160	169	8
Medium Gray Iron	18				
Limits		30–50	150–190	90–140	10–18
Extreme values		21–49	134–221	86–137	7–25
Very good results, jobbing		33	183	127	18
Heavy Gray Iron					
Limits		60–150	160–220	50–90	15–25
Extreme values		39–276	115–247	47–128	10–29
Very good results, heavy machinery (jolt)		96	191	74	21
Very good results, heavy machinery (slinger)		137	132	61	13
Light Malleable	16				
Limits		15–30	125–160	130–180	6–14
Extreme values		6–56	118–180	90–292	6–16
Very good results, jobbing (squeeze)		32	126	130	10
Medium Malleable	26				
Limits		30–30	130–170	90–130	8–15
Extreme values		23–49	120–172	82–149	7–16
Very good results		49	160	111	11
Heavy Malleable	14				
Limits		40–90	140–180	70–110	8–15
Extreme values		30–125	124–201	54–136	6–22
Very good results, jobbing (floor molding)		81	180	86	15
Light to Medium Brass	19				
Limits		10–25	130–170	190–240	7–12
Extreme values		5–23	132–221	145–291	7–25
Very good results		22	132	209	9
Heavy Brass	3				
Marine castings		38	135	103	6
Pump castings		80	191	94	20
Machinery castings		36	142	128	10
Aluminum	13				
Limits		5–15	130–170	180–290	8–25
Extreme values		4–18	140–195	136–294	7–34
Very good results		8	168	188	13

Appendix C

COMPARATIVE TEST DATA OF SIEVE SHAKING MACHINES

The tables listed below were made from data secured from tests comparing the operating times of sieve shaking apparatus with the amounts of sands remaining on the various screens of the standard series of sieves used in the A. F. A. fineness test.

Table 17 gives the results obtained with Ro-tap and the Great Western sieve shakers.

Table 17

COMPARISON OF RO-TAP AND GREAT WESTERN SIEVE SHAKERS

Same sample of grain with clay removed and same sieves used throughout these tests. Ro-tap was run 15 minutes with hammer in all cases. Tests were made in the order in which they are given below:

Machine:	G. W.*	Ro-tap	G. W.†	G. W.†	G. W.‡
Time run:	15 min.	15 min.	15 min.	20 min.	15 min.
On 6	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
20	0.2	0.2	0.2	0.2	0.2
40	0.1	0.2	0.3	0.2	0.2
70	0.6	0.5	0.5	0.7	0.8
100	1.0	1.3	1.4	1.4	1.5
140	6.3	4.8	6.3	5.8	6.3
200	19.1	18.7	17.3	17.9	18.4
270	21.4	20.0	18.4	18.3	17.3
Pan	30.0	33.9	34.1	33.6	33.2
Grain fineness:	210	218	216	217	215

*Without tappers. †Six tappers on one side. ‡Three tappers on each side.

Machine:	G. W.*	Ro-tap	Ro-tap	Ro-tap	G. W.†
Time run:	30 min.	15 min.	15 min.	15 min.	15 min.
On 6	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
20	0.2	0.2	0.2	0.2	0.2
40	0.2	0.2	0.2	0.2	0.2
70	0.7	0.8	0.8	0.8	0.8
100	1.3	1.2	1.2	1.3	1.4
140	4.0	4.7	4.5	4.7	4.9
200	18.9	17.5	17.9	18.1	18.6
270	18.3	18.7	18.7	18.2	17.6
Pan	34.5	34.4	33.9	33.7	33.3
Grain fineness:	220	220	219	218	217

*Three tappers on each side. †Six tappers on one side.

Machine:	G. W.*	G. W.*	G. W.†	G. W.‡
Time run:	15 min.	20 min.		
On 6	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
20	0.2	0.2	0.2	0.2
40	0.3	0.2	0.3	0.3
70	0.8	0.8	0.8	1.0
100	1.4	1.6	1.5	1.8
140	4.7	3.5	4.6	5.3
200	19.0	18.8	18.3	18.1
270	16.7	18.1	18.1	22.4
Pan	33.3	33.1	32.3	26.9
Grain fineness:	217	218	216	208

*Six tappers on one side. †No tappers (screens came loose and bumped sides). ‡No tappers (screens held rigidly).

Table 18a

COMPARATIVE TESTS OF SIEVE SHAKERS USING THE RO-TAP OF THE W. S. TYLER CO. AND THE SHAKER MANUFACTURED BY THE FOUNDRIES SUPPLIES MFG. CO.

Sand used: *Ottawa Banding Sand.*

Machine:	F. S. M. Co.			Ro-tap		
Time run:	30 sec.	30 sec.	1 min.	30 min.	30 min.	30 min.
On 6	....	....	....	....	....	....
12	....	....	....	....	....	....
20	....	....	....	....	....	....
40	1.47	1.41	1.40	1.36	1.38	1.38
70	11.49	12.71	11.12	13.33	13.67	13.14
100	34.33	32.48	32.73	35.59	35.54	34.16
140	26.37	28.43	27.95	23.87	22.88	24.26
200	14.36	13.28	13.85	13.27	14.00	14.15
270	7.88	7.60	7.54	6.83	7.07	8.08
Pan	4.24	4.12	5.41	5.65	5.43	4.82
Total	100.14	100.03	100.00	99.90	99.97	99.99
Grain Fineness Number A. F. A.	103.8	102.6	106.3	103.7	101.5	104.1
Grain Fineness Class A. F. A.	No. 3	No. 3	No. 3	No. 3	No. 3	No. 3

Table 18b

Sand used: *Ottawa Banding Sand.*

Machine:	F. S. M. Co.			Ro-tap	
Time run:	2 min.	2 min.	3 min.	30 min.	30 min.
On 6	....	....	....	....	....
12	....	....	....	....	....
20	....	....	....	....	....
40	1.34	1.28	1.22	1.32	1.32
70	8.69	10.34	9.71	10.42	12.33
100	29.93	29.02	29.04	32.26	31.60
140	28.27	26.67	26.93	24.89	23.80
200	14.93	15.41	15.29	15.87	15.62
270	9.76	10.44	10.29	7.87	8.25
Pan	7.10	6.24	7.11	7.12	6.16
Total	100.02	99.40	99.59	99.75	99.08
Grain Fineness Number A. F. A.	111.18	113.3	115	111	109
Grain Fineness Class A. F. A.	No. 3	No. 3	No. 3	No. 3	No. 3

Table 18c

Sand used: *1651*

Machine:	F. S. M. Co.				Ro-tap		
Time run:	30 sec.	1 min.	2 min.	3 min.	30 min.	30 min.	30 min.
On 6	....	....	....	....	....	....	....
12	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....
40	10.72	9.93	9.90	9.69	9.76	10.44	9.40
70	57.43	56.83	53.85	52.80	58.88	58.74	57.35
100	21.54	22.53	24.99	26.09	20.44	20.62	22.48
140	6.21	6.83	7.49	7.24	6.98	6.39	6.19
200	1.81	1.97	1.86	2.05	1.94	1.92	1.95
270	0.70	0.80	0.82	0.87	0.77	0.82	0.80
Pan	98.98	99.48	99.59	99.41	99.38	99.51	98.86
Pan	0.57	0.59	0.68	0.67	0.61	0.58	0.69
Total	98.58	99.48	99.59	99.41	99.38	99.51	98.86
Grain Fineness Number A. F. A.	52.5	53.7	57.5	55.6	53.3	52.7	53.2
Grain Fineness Class A. F. A.	No. 5	No. 5	No. 5	No. 5	No. 5	No. 5	No. 5

Table 19

COMPARATIVE TESTS SIEVE SHAKERS—USING THE ROTAP OF THE W. S. TYLER CO. AND THE VIBROTE OF THE TRAYLOR VIBRATOR CO.

Sand	Ottawa		Ottawa		No. 1654		P		No. 1661		No. 1662		No. 1663		No. 1664		No. 1665		No. 1666	
Machine	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote	Rotap	Vibrote
Time Run	30 Min.	10 Min.	30 Min.	10 Min.	30 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.	15 Min.	10 Min.
	←Per cent by weight remaining on sieve of the number shown in left hand column→																			
12	......	.....	......	.....	.....	.135	.....	.....	.....	.....	.....	.....	.....	.....	.253	.....	.....	.....	.....	.....
20	......	.....	......	.....	.095	.31	.....	.....	.....	.....	.....	.....	.....	.....	2.78	3.26	Trace	.665	.27	.28
40	1.480	1.90	1.455	1.455	15.16	15.19	7.30	6.810	5.68	5.29	16.30	15.70	2.72	3.20	17.40	16.55	2.24	2.88	2.07	2.18
70	17.560	11.07	13.005	10.085	64.62	60.18	16.95	17.00	21.60	21.05	51.10	47.80	16.10	14.30	24.80	24.10	16.24	15.78	16.20	13.90
100	32.590	32.76	33.100	33.500	14.88	18.52	16.80	19.05	16.65	19.50	18.55	23.00	37.05	37.55	36.40	38.20	38.50	38.80	41.50	42.50
140	22.21	30.21	25.155	30.150	3.29	3.32	13.95	15.40	9.60	9.10	5.61	5.45	21.25	27.00	11.85	10.60	21.60	24.80	24.35	28.60
200	14.38	12.81	14.645	11.790	.99	.78	10.19	8.40	13.06	11.58	2.62	1.88	9.50	6.85	2.54	1.83	6.68	4.51	7.76	5.06
270	4.86	.55	.610	.560	.080	.085	8.06	1.805	17.05	6.35	12.90	1.23	4.64	1.24	1.32	.35	2.55	.71	3.01	.67
270	6.57	10.81	11.945	11.055	1.12	.85	26.40	20.20	15.84	25.35	4.15	4.06	7.07	8.92	3.14	3.46	10.28	10.49	4.51	5.95
	←Per cent by weight passing through the sieve of the number shown in left hand column→																			
6	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
12	100.	100.	100.	100.	100.	99.86	100.	100.	100.	100.	100.	100.	100.	100.	99.75	100.	100.	100.	100.	100.
20	100.	100.	100.	100.	99.90	99.55	100.	100.	100.	100.	100.	100.	100.	100.	96.97	96.74	100.	99.33	99.73	99.72
40	98.50	98.10	98.54	98.54	84.74	84.36	92.70	93.19	94.32	94.71	83.70	84.30	97.28	96.80	79.57	80.19	97.76	96.45	97.66	97.64
70	80.94	87.03	85.53	88.45	20.12	24.18	75.75	76.19	72.72	73.66	32.60	36.50	81.18	82.50	54.77	56.09	81.52	80.67	81.46	83.74
100	48.35	54.27	52.43	54.95	5.74	5.66	58.95	57.14	56.07	53.16	14.05	13.50	44.13	45.00	18.37	16.89	43.02	41.87	39.96	41.24
140	26.14	24.06	27.27	24.80	2.45	2.34	45.00	41.74	46.47	44.06	8.44	8.05	22.88	18.00	6.52	6.29	21.62	17.07	15.61	12.64
200	11.76	11.25	12.62	13.01	1.46	1.56	34.81	33.34	33.41	32.48	5.82	6.17	13.38	11.15	3.98	4.46	14.94	12.56	7.85	7.58
270	6.90	10.70	12.01	12.45	1.38	1.47	26.75	31.53	16.36	26.13	4.53	4.94	8.74	9.91	2.66	4.11	12.39	11.85	4.84	6.91
270	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fineness No.	103.2	110.	111.	110.	47.2	47.2	144.	143.	131.	129.5	61.4	61.6	101.3	120.	64.	67.5	103.	110.	91.3	91.5
Class No.	3	3	3	3	6	6	2	2	3	3	5	5	3	3	5	5	3	3	4	4

Appendix D

To the Sub-Committee on Tests of the Committee on Molding Sand Research:

Your Sub-Sub-Committee on Core Tests wishes to submit the following report of its activities.

Comparison of Tensile Test With Other Methods of Testing Dry Sand Cores: The principal work of the sub-committee has been the comparison of the accuracy of the present tentative standard tensile test for determining the dry strength of cores with the transverse test, and with the flexure or bending test which is carried out on a baked A. F. A. permeability specimen which has been notched or slotted. Comparative tests were made under the supervision of A. C. Jones, using both single and multiple core boxes for preparing the tensile test specimens. The transverse tests were made using the equipment and method developed by H. L. Campbell, and the flexure tests as above indicated.

The results of the tests showed both the tensile and transverse tests to give consistent results, and the flexure test to be less dependable. Taking into account the influence of other variables not entirely under control, such as ramming and baking, it was the judgment of the committee that neither the tensile nor the transverse method showed any outstanding superiority.

The committee also circulated a questionnaire to secure information on the results being obtained in daily practice by the users of the various methods.

Taking into account the results of the tests carried out and the information secured from the questionnaire, the committee makes the following recommendation:

Recommendation: The committee recommends that the transverse method for testing cores be approved as an alternative tentative standard method for testing dry strength of cores, and that the necessary details, drawings and instructions be prepared for publication in the revised sand test pamphlet.

Suggested Supplemental Instruction for Making the Dry Tensile Strength Test for Cores: The committee has studied and discussed the merits of the present tentative tensile test method

for determining the dry strength of cores and makes the following recommendations:

Recommendations: The committee recommends that the tentative standard tensile test method for determining the dry strength of cores as given in the 1926 report of the Sub-Sub-Committee on Core Tests be supplemented with the following instructions:

A. Ramming: The single test specimen should be rammed with three blows of the A. F. A. permeability rammer. (If the multiple core box is used the specimens should be rammed with the A. F. A. Cohesiveness Rammer or with any other similar rammer to give the same degree of compaction as above.)

B. Measuring Sand for Specimen: The test specimen should be prepared by the use of such a volume of sand as will give a specimen slightly in excess of one inch in section after ramming, the excess sand being removed with a cut-off device or knife, which is arranged to cut off the specimen in the box to a one-inch section.

C. Revision of Core Box: The committee recommends the use of a revised type of core box which incorporates a hopper for holding the proper volume of sand, a loose rammer head for compacting the sand under the rammer and a knife for cutting off the specimen to a one-inch section.

Respectfully submitted,

E. R. YOUNG, *Chairman,*

Sub-Sub-Committee on Core Tests.

Committee on Foundry Sands
Report of the Sub-Committee on Conservation and Reclamation

To Members of the American Foundrymen's Association:

The Sub-Committee on Conservation and Reclamation has not met as a group since the Chicago Convention of 1927, until the wêek of May 14th.

The committee's activity has been to keep abreast of developments in conservation and reclamation work, feeling that the work of conservation and reclamation is now so well established that further effort is not required.

The work of evaluating clays or high bonded sands for conservation of molding sand continues, but now under the direction of Dr. Ries' committee on sand testing. Upon this the committee reports progress.

In order to indicate the extent of progress of conservation through technical control and the use of clay or highly bonded sands, various producers and users were again canvassed, with a distinct indication that during the past year conservation and reclamation have been further extended. There are noted below some of the statements contained in the replies from various producers in reference to clay bond or other highly colloidal products which have been received by the committee.

One producer states: "In the calendar year 1927 we shipped over 30,000 tons of bond and indications are quite positive that shipments in 1928 will not be less than 50,000 tons. This compared with a figure of 16,000 tons for the year 1926." Another producer reports as follows:

"January, February and March, 1927, 23 carloads. Same period, 1928, 86 carloads." Still another producer reports:

"Our sales indicate beyond any doubt the acceptance of clay bond on the part of the principal foundries in the Cen-

tral States. For the first three months of this year our sales were three times as great as the corresponding period of 1927, and we fully expect to maintain this proportion, if not exceed it, for the balance of the year. We now have about 125 customers on our list of regular users as compared with 75 which we reported to you prior to the Chicago Convention."

Of further interest, the same producer states that each of their engineers carries with him a portable sand testing laboratory, and that in the field of testing, sand reclamation has already done its bit to emphasize the importance of sand control. This producer goes on to say that they have seen a wonderful increase in the adoption of control methods by foundrymen everywhere during the past year. These methods, it is stated, lead to investigation of comparative merits of sands and bonds. Definite factors of strength are replacing the somewhat indefinite determinations of so-called "bond substance" in comparing raw materials, as they are replacing the "feel" method in control. Durability of sands and of clays is recognized as an important factor.

The same producer states that new avenues of research and endeavor have been opened up during the past year through reclamation work, not the least of which is the development of clay bonded synthetic sands. That is to say, low cost sharp sands bonded with clay bond of one nature or another by the producer as well as by the user for the preparation of synthetic sand.

There is noted below statements taken from the replies of various foundries, which were made to the committee in answer to the committee's inquiries covering the subject of clay bonds.

"Replying to your letter of April 14 regarding the use of clay bond in our plant. Since our last communication on this subject, we have increased the use of this material to a point where it has replaced all our molding sand.

"At the present time we are using two materials. Our daily tonnage of good castings at the present time is running around 630 tons. I think that we have gone through all the phases and all the trouble of this kind of a change-over and can only pronounce the use of clay bond a complete success, and I am thor-

oughly satisfied that we will never go back to natural molding sand. It might interest you to know that we are just installing equipment to bring in seven carloads of refuse sand a day, part of which will be used in cores."

Another manufacturer replies: "We are still using clay bond in our molding sand. This has been our practice for the past four years. We have found this to be economical, as our present requirements are only one quarter as much as formerly."

A large motor car manufacturer reports as follows: "In answer to your letter of April 14th, regarding clay bond, we are still using it 100 per cent in our iron foundry and while I am unable to give you any figures comparing the cost of a clay bonded sand with a natural bonded sand, I feel I can safely say that the results are satisfactory and that the scrap and defective castings charged to molding sand is very low." Another foundry reports as follows: "We are still using clay bond in large quantities for rebonding our molding sand, and find it economical."

Another large company manufacturing motor castings reports as follows: "In reply to your recent letter of April 14th, in regard to the subject of clay bond for molding sands, etc., this is to advise you that clay bond is still proving successful in our opinion and we consider its application very economical. I may add that we have been using clay bond continually since the year 1919, and each year sees an increased application and closer supervision in the use of this material."

A large manufacturer of railroad equipment writes your chairman as follows: "Answering your letter of the 14th on the subject of molding sand bond. We are still using a clay bond in our malleable foundry without the use of new sand, except in cores.

"In our steel foundry we are using the same clay bond but are using about 300 pounds of new sand per ton of castings.

"My personal opinion, based on our experience in both malleable and steel, is that the average foundryman does not accord his heap sand the necessary attention. If your committee can direct the foundryman's interest to the heap, rather than the facing, a service will have been done for the industry, particularly so in the steel foundries.

"For several years we have paid more attention to the condition of our heap (backing) sand with very satisfactory results. By using a durable bond—one that continued to develop strength, without being used in excessive quantities, and maintaining high permeability—we have been able to eliminate all facing sand in malleable and reduce our steel casting facing material. With this there has been a higher rate of producing copes, especially on large molds, because of the stronger sand."

A large producer of motor vehicles reports through the foundry metallurgist that "we are using clay bond quite successfully and have made considerable improvement in our sand due to controlling the bond. We have had success with both natural bonds, clay and bentonite. There is no doubt in our minds but that the use of bonding material is economical. We are only in the experimental stage as yet, but see no obstacle in the way of bonding all our sands.

"We will be glad to co-operate with you along this work and give your committee the benefit of our experience at any time."

The following is from a letter from one of the large motor car producers.

"The results of the introduction of clay bond into our foundry considerably over a year ago have been beneficial and far-reaching. Prior to that time we had been using a heavily bonded natural molding sand having a low fusion point. The use of this sand gave us the following cycle in our sand-handling systems: a strong, tight sand, causing scabs and blows. As the sand was used, it lost in strength and gained in permeability and we had a period of fairly good results. Due to the fact that the sand lost its bond rapidly, we soon passed through this good period and entered one of excessive drops, caused by weak sand. To remedy this condition, more new sand was added, and the cycle started all over again. We had very little control over these conditions and simply had to put in new sand when the amount in the system was low. We could not reclaim any old sand because it contained too many fines. This natural sand burned in badly on the castings, giving them a poor finish and causing high cleaning costs. It was with the idea of eliminating the above troubles that we decided to use clay bond.

"Upon the recommendation of the engineers who were servicing the case for us, we installed sand testing equipment and went at the control of our sand in a thorough and scientific manner. Standards were established for strength and permeability and rigidly adhered to. Ottawa silica sand was used as the base sand, being exceedingly refractory and at the same time very permeable. Enough was added daily to take care of the natural wastage. It can be readily seen that it was an easy matter to hold to the standards established by increasing or decreasing the amounts of clay bond, silica sand and old sand added daily.

"The beneficial effects were immediate. The sand was kept open enough to prevent scabs and blows and at the same time strong enough to prevent drops. There was a tremendous improvement in the appearance of our castings. Burning in practically ceased and the resultant finish was a great deal smoother than before. In fact, a prominent foundry man connected with the automobile industry stated a short time ago that we were making the best looking cylinders he had ever seen. It might be stated in passing that since we started to use clay bond we have not added a pound of new molding sand to any of our systems."

The following is from one of the largest producers of motor cars and is, in the opinion of the committee, particularly interesting, not because of the tonnage of clay bond employed, because after all, this is relatively small compared to many plants, but because of the attitude and significance of the remarks.

"In answer to your letter of April 14th relative to sand reclamation and conditioning by the use of fire clays or similar materials; will state that we used last year, twenty-five (25) cars of rebonding material and would have used it 100 per cent in our shop if we had sufficient equipment for conditioning all of our sand.

"We believe the practical application of reclaiming refuse sand has been thoroughly demonstrated. It seems to be a survival of the new against the prejudices of the old. As younger men come into control more reclamation will take place.

"The above is for your information and trust the committee may have a favorable report at the convention."

The committee wishes to point out the importance of sand testing and control as an adjunct to a successful conservation program.

The committee would also call to the attention of the prospective users of clay bonds or highly bonded sands the possibilities of well selected sand free from bond as a distinct help in our conservation program.

The replies from representative producers and users leaves little doubt as to the magnitude of the movement toward conservation of molding sand through the intelligent use of clay bonds and highly bonded sands.

In conclusion the committee again desires to point out the possibilities in the field of sand conservation through the application of intelligent methods and materials.

Respectfully submitted,

R. F. Harrington,
Chairman

A Contribution to the Study of Labor and Staff Training in Foundry Work[1]

By A. Soupart, Morlanwelz[2] Mariemont, Belgium

Development of the Industry

If we look back over the industrial and commercial activity of the past fifty years we cannot but be profoundly impressed and filled with admiration at the advancement made.

Under the impulse of scientific and technical progress and by the application of more systematic methods of organizing labor, industrial enterprises have undergone a profound transformation, which has also involved the adoption of new and better conceptions of financial organization.

It does not appear too much to assert that the foundry industry, the most ancient of the arts, has kept pace with this movement only imperfectly, and that at the close of the last century it did not occupy the position in the iron and steel industry which it might have claimed.

The influence of routine was too strong and, it must be admitted, the necessary theoretical and technical factors were lacking.

The transformation of the foundry industry was therefore slow both in spirit and in its methods, by which it tends increasingly to become, from the industrial point of view, really an applied science, based on metallurgy.

Thus during the past quarter of a century, and more particularly since the years following the war, we have witnessed a profound evolution in the industry, almost without precedent, which has led to the remark that it appeared to be anxious to make up for lost time. We may admit that it was really necessary for it to do so.

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[1] Presented on behalf of the Association Technique de Fonderie de Belgique.

[2] Director of the State Vocational Museum and of the Industrial and Vocational School.

The Need for a Better Supply of Skilled Labor

When scientific and technical factors operate so powerfully on an industry as it does on the foundry it is desirable that the human factor which also contributes to its development should not be disregarded. It is necessary therefore that the standard of skill and craft consciousness should be raised, so as to constitute a working staff of the highest quality, which is indispensable to an industry which desires to live and develop.

The foundry trade cannot dispense with a serious system of technical training any more than any other occupation. Scientific progress and its effect on industrial evolution does not permit of this, and it is indispensable that sufficient intelligence and initiative should be introduced to enable the labor employed to accommodate itself constantly and smoothly to the successive changes to which the industry may be subject. On this subject, agreement is general. For this reason the organization of a methodical and rational system of apprenticeship, carried out systematically and intensively, is of great importance to the future of the foundry industry. It is, moreover, high time that this should be done, for it must be acknowledged that technical instruction in foundry work has been greatly neglected and that it is desirable to see it take its proper place without delay.

It most cases the great obstacle to the development of apprenticeship giving an adequate supply of workmen is the difficulty in obtaining recruits in sufficient quantity and of the requisite quality.

In Belgium the industry is, relatively, fairly scattered, and in the industrial centers where it does not predominate the trade is little sought after and is often neglected, chiefly in favor of skilled employments in engineering and the electrical industry.

From the figures published by the Syndicate of French Foundrymen it appears that to insure the necessary quantity of labor, it is desirable that each works should take at least 5 to 7 apprentices annually for every 100 workmen and laborers employed, or say about 10 per cent to allow for losses during apprenticeship. These figures seem to approximate to our own needs, and it must be admitted that we are far from reaching them.

It has been objected that the trade is rather unhealthy, looked down upon, dirty in the real sense of the word, does not

call for the special knowledge required elsewhere and is, moreover, not exempt from danger. Certainly every trade has its own risks, but it must be said that the present arrangement and organization of foundries have materially improved the position of the working molder in this respect. The work is, in fact, much less irksome and more hygienic than formerly.

Is it not well also to emphasize the fact to those who prefer, without quite knowing why, to go into other engineering occupations, that foundry work also is a question of engineering and that—and this is an important point—the trade is not overcrowded and wages are as high as in other branches, if not higher?

While the absence of apprenticeship of a systematic nature is seriously felt, one of its causes incontestably centers around the question of wages. The apprentice does not understand, and his parents still less, that sacrifices must be made to learn a trade rationally. No, they consider that they ought to be paid and well paid from the start.

Machine molding has made enormous progress during the last 20 years. Unfortunately it must be admitted this has been to the detriment of apprenticeship, for the workman who works a molding machine is not a skilled workman. He is merely a specialized laborer of whom strength and rapid work, but not intelligence, are chiefly required.

With the present organization of machine work in the foundry this specialized laborer, if he is brawny and industrious, so that he can produce a large output, will be quite as well, if not better, paid, than the working molder. The young molder therefore, after a few years' probation, or even in a few months, especially if he has a robust constitution, will always endeavor to be put to work on a molding machine because he will be better paid.

It is for this reason that foundries specializing in work adaptable to machine production—automobile and electrical castings, heating apparatus, piping, etc.—have no difficulty in obtaining labor, while foundries engaged chiefly in producing machine castings can no longer obtain the necessary skilled labor except with great difficulty. It is mainly in hand molding therefore that the scarcity of apprentices is felt.

Certain types of work which are easily learned and soon remunerative, such as machine molding, therefore involve a certain danger to the development of a rational system of apprenticeship, as the need for it does not appear to the possible apprentice so imperative owing to the high wages which are easily obtained, particularly at times of labor crises.

It is hardly necessary to repeat that the old system of apprenticeship in the works, which consisted in letting the apprentice help the experienced workman, thus enabling him gradually to absorb the principles and acquire the manipulative skill incident to the trade, seems no longer practicable today with fruitful results. In the first place it has been found that this method of training is too empirical, and while it must be admitted that in certain isolated cases it might still give good results, its adoption is becoming more and more rare.

Working methods have been modified. The factors of time, movement, muscular effort, etc.—in short, everything entering into output—have assumed enormous importance. The craft consciousness is no longer the same, and therefore apprenticeship by example would only produce insignificant, if not negative, results destitute of the spirit of discipline and would be too much tainted with empiricism.

It is indispensable, therefore, that this state of affairs, which is very serious for the future of the foundry industry, should be energetically remedied. By means of systematic organization it is possible to raise the technical status of the trade, to make it more interesting and, in particular, more attractive, while at the same time improving the craft consciousness of the industry.

Inadequate Training of the Supervisory Staff

In the present position of things, the recruitment of overseers is intimately bound up with that of labor.

In the great majority of cases foundry foremen have trained themselves and have been selected from among old molders of intelligence who, under the force of events, have learned to work a cupola. No doubt the selection of these men was prompted by the superior qualifications distinguishing them, and particularly because they were rapid and good producers and showed competence, initiative and decision. But it is none the less true that,

as regards general education and technical and scientific training, they possess—and I am far from ignoring its value—only what they have learned by experience.

On the other hand, in view of the profound transformation of the industry which has been emphasized at the outset of this paper, it is constantly found that this training is inadequate, that it is a cause of diminished production, and that sometimes it has even made itself—whether unconsciously or not—the accessory of errors on the introduction of new methods, owing to a lack of vision and inability to adapt itself to the facts of progress. Witness the difficulties met with long ago when molding machines and metal patterns made their appearance.

While in our industrial centers it has become almost exceptional among the present generation of foremen and shop managers not to hold a technical school diploma, the case is different with the responsible overseers in foundries.

We must not forget, however, that the foreman is the mainspring of the foundry and that its output is dependent upon him. Without attempting to detail completely the requirements of his functions and responsibilities, it may be said that he must possess in particular a thorough knowledge of molding and patternmaking and be able to study methodically the various cases which arise and give his workmen precise instructions before starting the work of manufacture.

The workman must be directed both before and during the work, particularly in making complicated castings, and if he feels that he is being intelligently helped, the pace and the results of the work will be all the better. It is necessary, therefore, that the instruction given by the foreman shall be applied and that he shall see that the orders given are followed.

The foreman must also be familiar with the melting apparatus, and in operating them he must be guided by theoretical knowledge and an adequate comprehension of the phenomena produced in them.

It is no less essential that he should display a thorough knowledge of the psychology of the foundry workman, that he should know how to manage men and that he should possess well informed ideas regarding the modern organization of labor and all the factors which enter into cost price.

From all this it appears indisputable that if we wish to find men suitable as foremen among the workmen—and in this there are many advantages—the greatest attention must be devoted to training as well and as completely as possible those who will be called upon later to become the direct collaborators of the directors of the industry.

Foundry Workers and the Technical School

I think we may classify founders, core makers and molders under the one general description of foundry workers, as the knowledge requisite for complete training is essentially the same in each of these categories.

It has frequently been found that the work of the young molders requires to be supervised very closely and in the smallest details. Moreover, the temperament of our young men is far from fitting in with the exigencies of the trade. The work is done too mechanically and consequently without that spirit of observation and reasoning which is so necessary to the intelligent exercise of the trade.

This state of things, in my opinion, is to a large extent due to the lack of continuous contact with the technical school. In any case it may be stated that the number of young molders receiving supplementary general instruction and scientific and technological knowledge of the trade is somewhat restricted, and that the average percentage of attendance is for the foundry trade materially below the figure of 5 per cent, shown by the other Belgian industries.

From this standpoint the classification of the molders of school age may be made as follows:

1. Those who do not take advantage of any industrial and vocational instruction, and who merely train themselves, as best they can, by the old method. These form the great majority.

2. Those who attend the courses of an industrial school with the view of entering the special course of workshop technology, in which only one section of the syllabus deals with foundry work. These pupils are somewhat rare.

3. Those attending the special foundry section of a full time vocational school. There are few of these schools in the country; their complete organization, for the purpose of creating

auxiliaries to the foundries, would be very difficult, if not extremely costly. The apprentices trained in this way are few in number.

4. Those attending evening improvement classes. The organization of these courses is not yet general in the districts where the foundry trade is carried on, and consequently the number of pupils is relatively limited.

5. Those attached to the molding-school shops of the foundries themselves. These schools have been established by certain large companies, and the number of pupils would be satisfactory if these schools were more general.

6. Those who, being desirous of improving themselves from a general and technical point of view, attend the classes of some school, their purpose being to get out of the trade. These individuals are perhaps more numerous than is supposed, and this is really regrettable for the industry.

While the reasons for this state of things are well known, we may perhaps also regret the fact that our instruction in foundry work is not organized on a sound basis and in a sufficiently attractive and interesting spirit to induce the workers in the trade, as in others, to have recourse to it.

Observations on the Methods of Instruction

It appears that the system of training should differ distinctly according as the aim is to produce good skilled workmen or to give advance training to foundry foremen. The training of apprentices must not be confused with that of foremen. In my opinion, they are two absolutely distinct things.

No doubt there may exist points common to both, as everything is dependent on the inclination of the pupils, their previous education and the number of subjects to be taken in the different stages of the instruction in view.

The step for which the need is greatest is undoubtedly the institution of elementary courses as a basis of training for the working molder. These courses might be either permanent or temporary according to circumstances. The need for these courses being most pressing they should receive first attention.

At the International Congress of Technical Instruction held at Charleroi in 1925, I suggested the establishment of temporary

courses with a restricted syllabus and with an essentially experimental and vocational tendency. Workmen were to be admitted to them without any conditions as to matriculation or preparation, and the courses would be of short duration.

The principles on which the industry is based would be ably and simply explained. These courses, which would be led by specialists, would have the advantage of at once interesting a large number of manual workers, the best of whom would be retained *for further instruction,* so that an excellent nursery of recruits would thus be formed for subsequent training.

After these temporary courses how many pupils should we not see definitely converted to the necessity of perfecting their scientific and technical equipment? An astute teacher could, moreover, be sufficiently persuasive to interest his temporary pupils in the whole range of the technical knowledge affecting their occupation and to inspire them with the creative desire to do and to know more.

Such is the first stage of the scheme which I regard as necessary to be carried out. The organization of these courses, in my opinion, will provide numerous opportunities for doing excellent work, for apart from the immediate vocational result it will contribute greatly to increasing the attendance at our technical schools from among the mass of workers who are at present untouched by any kind of instruction.

But in order to impress parents and young men with the whole future held out by the foundry trade, is it not desirable to convince pupils who show the requisite natural disposition, fortified by genuine intelligence, of the possibility of making their mark, by holding out to them the prospect of a career within their means?

Under a democratic system the young workman, if he has the necessary aptitude and proves it, must be allowed access to the highest posts. And it is the imperative duty of the industry on its part—as of society as a whole indeed—to seek and discover this aptitude and to encourage its fullest development.

Whatever stage of instruction may be in question, there is one general principle to which I should like to call attention. The training must have a certain coherence, dominated by a powerful stimulus, so that at its different stages a well graduated system of instruction may enable the pick of the apprentices to pass from

one stage to another and thus reach the different grades among the higher posts.

In this connection the recent establishment of the Higher School of Foundry Work in France has supplied a want, by satisfactorily completing the execution of an entire scheme for the purposes I have indicated, the enormous effect of which will assuredly not be long in making itself felt.

The instruction to be promoted will insure, in conjunction with manual training, supplementary general instruction and as complete as possible an initiation not only into the art of hand molding, but also the materials used, melting and the use of the machines.

Where can this instruction be given? The answer appears simple and economical in regard to the instruction which is supplementary to that of the elementary school and that dealing with the scientific, technological and educative parts of the trade. Opinion is hardly divided on this subject, that our industrial and vocational schools could organize and reorganize special foundry sections so that syllabus and methods may be quite suitable to the needs of the industry. Certain preparatory courses may even be the same as those for other special industries, although it seems desirable that the foundry workers should be grouped together. In this way the second stage of the scheme will be realized, that is, if we may so call it, the theoretical training for the trade.

Opinions differ, however, when we come to apprenticeship proper, aiming at manual training.

Contrary to the ideas generally prevalent at present regarding apprenticeship in the engineering trades, it is admitted by many manufacturers that a systematic and complete training in foundry work can hardly be given except in the works themselves. This is the method practiced particularly in France, Germany, the United States, etc., and by certain Belgian works. For unless well equipped schools are available, capable of actually reproducing the life of the foundry, with regular and sufficiently numerous casting demonstrations, multiple casting apparatus, etc., which would involve enormous cost and is therefore impossible except in isolated cases, it is recognized that the apprentice cannot be trained effectively except in the shops—amid the surroundings and regular operations of the foundry.

Owing to the many advantages which it presents, I remain a firm advocate of apprenticeship in the school, subject to such schools being regional and, in particular, to their being supported indiscriminately by all master foundrymen. In my opinion this is a condition indispensable to success, a condition to be combined with the granting of an apprenticeship wage, so as not to keep away young men who would have every interest in attending the schools owing to their having to make too great financial sacrifices for two or three years.

If this training is given in the workshop it ought, I think, to be subject to very radical conditions. If apprenticeship is served in the molding-school shop established in the foundry itself, it is necessary that educational methods shall be transplanted there, otherwise something like chaos will always reign. The atmosphere of these shops must therefore be that of the school.

By means of strict regulations, not however without a reasonable measure of consideration, a sound system of discipline, freely accepted, will be established. This state of mind will react with good effect upon punctuality and the inclination for work, and will undoubtedly excite the most salutary spirit of emulation among the young men.

The objection to such an organization within the works themselves is the difficulty of finding the apprenticeship teacher required for each plant employing 40 to 50 workmen. I do not ignore the importance of this drawback, for the choice of an apprenticeship teacher is always a large factor in success. This difficulty, however, is not peculiar to the foundry industry; it is also encountered elsewhere, both in regard to the school in the workshop and the workshop in the school, and we shall see later how, in my opinion, it is possible to remedy it within a fairly short time.

For the training of foremen, special higher courses held in the evening and on Sundays would receive pupils from the special courses of the intermediate industrial schools.

I think I cannot do better than reproduce here the passage from the report of the Studies Committee of the "Comité industriel de l'enseignement professional et technique de Belgique" ("Industrial Committee for Vocational and Technical Instruction of Belgium") on the organization of courses in foundry work (year 1927):

"The following results appear from the inquiries conducted in circles familiar with foundry work by the Masters' Association or Technical Foundry Associations:

"1. The general opinion is in favor of apprenticeship served in the workshop for the training of workmen, but to be profitable this apprenticeship must be organized methodically. It recommends that apprentices should be trained in sections under the direction of a workman selected on account of his qualifications and character, and that the apprentices should not be distributed among the workmen in the foundry until the end of the second or even the third year.

"2. When the apprenticeship in the school is unavoidable it should be completed by a fairly long period of training in the workshop. Owing to the compulsory restriction of their foundry workshops the vocational schools ought to confine themselves to training apprentices who are likely to become skilled workmen, and more particularly, to developing in their pupils the spirit of observation and research which are among the most necessary qualities to the industry, for the purpose of inducing them afterwards by all possible means to complete their training by a period of several years in the foundries."[3]

The Fonderies de France suggest that: "The vocational school should be organized not only for the purpose of admitting educated young men in order to give them vocational instruction, but also for that of completing, by a course lasting a few months, the training of selected workmen and young foremen entering the industry direct from their apprenticeship. This course, while occasioning but little expense, since elements and material existing for other purposes would be used, will rapidly raise the status of the industry.

"In their engineering vocational schools, however, the public administrations might establish a foundry section in conjunction with the fitting, pattern making, forge and machine tool sections. As the French, mathematical and science courses, and in part the drawing course, are common to all the sections, the expenditure involved for the purposes of the new section will not be very considerable. With regard to the foundry workshop, the establishment of which is essential, it will serve equally for the evening courses, which will nevertheless constitute the principal organism in the formation of nuclei for the supply of foundry foremen.

"This foundry section established in the vocational school will complete the harmony which ought to exist between the different branches of mechanical engineering.

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[3]After a careful examination of the various opinions, however, the Apprenticeship Commission of the Syndicate of French Foundrymen considers that the vocational value of the workman cannot but be increased by his passing through works other than that in which he was trained, and the Commission of Vocational Instruction of the North of France goes further and admits that apprenticeship ought not to be served entirely in the same works. Totally contradictory opinions were expressed, and the general opinion is that, if apprenticeship were systematically instituted both by private industry and by the public administrations and services, labor would be sufficiently plentiful to cause nothing but advantage in seeing apprentices, at the end of their term, complete their training by entering, for a time at least, foundries other than those in which they were trained.

"Here, however, an important question of organization arises:

"In the workshop should an apprenticeship section, with a foreman as teacher be organized, or should each pupil be attached to a good workman?

"The answer of those most competent in the matter is as follows:

"1. In large plants it is absolutely indispensable that the apprentices should be grouped under the direction of a carefully selected teacher;

"2. In medium or small foundries the apprentices should be put to work with skilled workmen who would be in charge of them. These apprentices, however, should be the subject of very special attention and supervision on the part of the foundry foreman, if he wishes the trouble taken by himself and his subordinates to have profitable results.

"But how is the distinction between a large and small works to be defined? Ronceray in France and Léonard in Belgium reply:

"Reckoning that every foundry ought to have a number of apprentices at least equal to one-tenth of the skilled workmen it employs, with a minimum of 1 or 2 apprentices;

"Assuming, moreover, that with a number of apprentices exceeding 5 or 6 a separate teacher is an advantage and could very quickly enable his employer to recover his salary;

"Every foundry having 40 to 50 workmen ought to have its special teacher.

"Those who have studied the question consider that the systematic training of apprentices in the works does not necessarily mean a financial sacrifice when it is well managed; they calculate, on the contrary, that it is even profitable, if only from the point of view of cost price.

"Nevertheless we are far from seeing this methodical and rational system of organization become general.

"The Syndicate of French Foundrymen did not venture at once to adopt the obligation of apprenticeship, mainly because it appeared difficult in the absence of legal provisions to impose its decisions when they were taken.

"It is, however, studying the question of obligation by mutual consent, suggesting as penalties those already in use by the Trade Syndicate of Mechanical and Naval Construction of Nantes and the Loire Inférieure, which consist in making each employer unable or unwilling to take a number of apprentices fixed in advance pay a sum of 500 francs for each apprentice less than the number fixed[4].

"It remains for us, therefore, to keep our attention fixed on the capital question which dominates the entire problem: 'the recruitment of young men as molders' apprentices.

"It must be admitted that hitherto the trade has been in poor repute. A molder is supposed to be a man without any pretentions, and without any need for the higher training which fitters, engineers, turners, etc., consider—rightly moreover—to be indispensable to them.

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[4] These decisions of the Syndicate of French Foundrymen preceded the passing of the French Law on the Apprenticeship Tax.

"A lad about to become an apprentice generally wishes to be an engineer or an electrician, without knowing very much about the matter.

"It is therefore necessary to take very serious measures to insure the recruitment of apprentice molders. The action of the masters in this matter must be of an intensive nature. It will be really efficacious if they grant attendance prizes for those of their workmen who attend the evening courses of the vocational school, and if they insure an immediate increase of salary to those among them who obtain diplomas. This decision has already been taken by the members of the Technical Foundry Association of Belgium."

In the ensuing stage, the purpose of the secondary school, either working full time or in the evening, would be the training of the intermediate supervisory staff and the works managers.

And to complete all this, seeing that our university instruction does not, properly speaking, produce foundry engineers, why should we not see established in Belgium, as has been done in France, and in conformity with our needs, a higher school of foundry work open to well educated young men who have completed the preliminary studies necessary and who—this being an indispensable condition—have acquired a certain knowledge of the industry.

I have summarized below in diagram form (see Chart 1) the plan of this entire organization as I envisage it.

If it differs somewhat from that recommended by the Industrial Committee for Vocational and Technical Instruction forming part of the Central Industrial Committee of Belgium, this is because I am desirous of reaching the largest possible number and have therefore given greater importance to the elementary knowledge required by the workmen who have received no instruction, and this in order to proceed at once to what is most urgent. The organization recommended, however, is the same in its main lines.

The Guiding Principles of Training

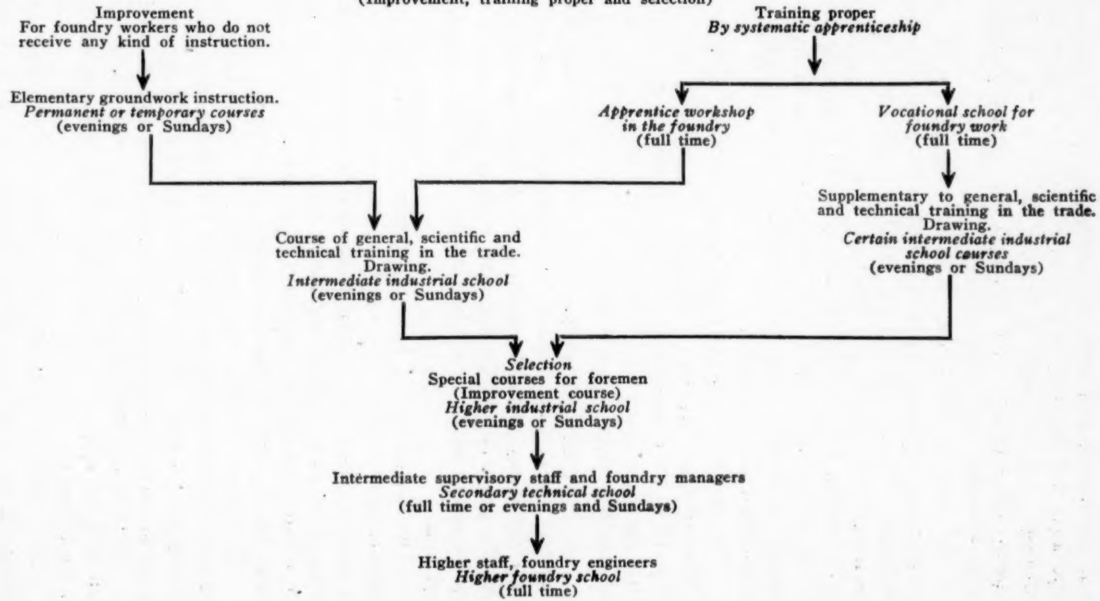
I have shown that any action taken must be governed by the essential idea of enabling both the foundry workman and the permanent supervising staff to break away from routine and empiricism, to be the masters of their trade and not its slaves.

Practice, in order to be enlightened and sufficiently flexible to accommodate itself to changes in the work, must be based upon

Chart 1

SCHEME OF VOCATIONAL, SCIENTIFIC AND TECHNICAL TRAINING FOR THE WORKMEN AND STAFF IN FOUNDRY WORK

(Improvement, training proper and selection)



well determined and well assimilated theory. The lessons of experience will then only have greater force and greater educative influence. Let us make no mistake therefore; the ends to be attained are complex—of a technical and intellectual as well as of an economic and social nature.

A. General Education. It is no exaggeration to say that the educated workman may be regarded as the only really qualified workman. The general training of labor ought not to lag behind the material of production. We must therefore improve its general education and cultivate its intelligence by continuing the work of the elementary school with general courses in the mother tongue, arithmetic, geometry, industrial drawing, hygiene and social and trade economics.

By means of examples judiciously chosen, moreover, this instruction may very well be adapted, as regards certain of these subjects, to the requirements of those disposed to enter the trade. Thus the applications used in the geometry, drawing and mechanical courses might be made specially to illustrate foundry work.

B. Scientific Instruction. The practice of the trade demands a certain intelligence, trained by observation of and reasoning upon elementary ideas of certain physical and chemical phenomena, the properties of the materials worked upon from the sand and accessory products to the cast metal, and air, water, gases and heat.

The molder should have instruction in certain elements of mechanics, a knowledge of which is necessary not only in order to make a proper use of the mechanical equipment, the importance of which is certainly increasing every day, but also because the foundry has special machinery of its own. All this demands vocational as well as extra-vocational qualifications.

C. Manual Training and Duration of Apprenticeship. If we are to be methodical and complete we must not confound apprenticeship and training. Manual training should therefore constantly be based upon theoretical instruction and technical education.

The practical work will therefore be carried on in conjunction with the subjects taught in the technological courses relating to the industry.

By means of practical work methodically drawn up and graduated, the apprentice will be systematically initiated into the

life of the foundry, the manipulation of the tools, the materials worked, the processes employed, the different kinds of molding, etc.

The typical castings to be made will be arranged in order of increasing difficulty, and all this work will be discussed and examined in detail. The manual movements will be explained and illustrated.

The apprentice, for example, will learn in each case the reasons for the respective positions of the risers and runners.

All these processes will be classified and employed under different conditions so as to show their advantage in each particular case. The pupils will be trained to note them carefully and to look for the effective causes of the results which they enable us to obtain.

The castings produced by the apprentices will be such as are actually manufactured for practical use. The preparatory work, as also the fixing of costs, will naturally be grafted on to the work to be executed and the work turned out, so as to permit of a comparison between the estimated and the actual figures, which is so useful. Thus equipped, the apprentices may be distributed among the foundry staff at the end of the second or after the third year of apprenticeship, while continuing under special supervision. For it appears from a careful examination of the opinions given that the term of apprenticeship ought not to be longer than three years, whether it is served in the workshop or at the vocational school. That it is desirable for the apprentice afterwards to leave the works which may have trained him, so that his value may be increased, no one will question as soon as systematic apprenticeship has become sufficiently general. Skilled labor will then be sufficiently plentiful, and nothing but advantage will result from apprentices completing their instruction and perfecting their experience by taking work elsewhere.

Concurrently with the qualifying certificate for the trade given on the completion of apprenticeship, an effort should be made, as far as possible, not to permit admission to specialized molding work until after a specified age, when the evidence of sound training has become certain.

D. Technological Instruction. The technology of foundry work, which is very important from the point of view I hold, should be inspired largely by the scientific principles already de-

scribed, as the two are inseparable. The instruction will, however, be extremely concrete as all the operations in the industry lend themselves admirably to such treatment.

All the typical operations—the working of the apparatus, the preparation of the sand and molds and the subsequent operations—will be summarized on instruction cards.

Certain tasks set will be for the purpose of discovering possible means of increasing production, so as to inspire that excellent method of work in which the output is constantly kept in view without losing sight of the quality of the product.

Technological instruction demands practical demonstrations, not merely verbal but made tangible by facts. An illustration of this idea by an example would be a practical demonstration of the defects caused in castings by contact of the materials—sand and cores—with the molten metal.

The same field of experiment is open in regard to the composition of the metal poured, if it is desired to determine the properties and characteristics of the castings obtained. At a higher stage of instruction, test pieces from all castings poured would be made and taken by the pupils, who would afterwards make strength, elasticity, brittleness, resilience and other tests, to be supplemented by a study of the effects of thermal treatment. Finally, all these tests may be repeated according to the nature of the metal cast, whether ordinary machine castings, special cast iron, molded steel, bronze, anti-friction metal, aluminium or duraluminium, etc.

While familiarizing the apprentices in this judicious manner with the unforeseen and unsuspected elements in the industry, this training is likely to achieve another purpose no less essential: that of definitely stimulating innate aptitudes and unused faculties which require only to be guided and prudently spurred on to be of great value to the industry.

E. Recruitment and Vocational Guidance. Recruitment must be understood in the sense that there shall be harmony between supply and demand, and that no confusion shall be possible between the skilled workman who has been systematically trained and the specialized laborer—a situation liable to result in dangerous competition likely to exercise a regrettable reaction upon apprenticeship subsequently.

Recruitment must for the present take into consideration the physical, intellectual and moral qualifications regarded as being most useful in efficiently practicing the trade. Special preference must be given to physiological characteristics favorable to good health and admitting of sufficient and sufficiently energetic activity such as is required for the rapid and intelligent execution of foundry work, as well as to the sense of attention and observation and the necessary faculty of patience.

F. Educative and Moral Import. Finally, it would be a social danger to regard the laborer as being merely a tool. The workman, like the foreman, must be a man in the full sense of the word, conscious both of his duties and his rights and possessing the sense of responsibility in a very high degree, in proportion as he rises in the hierarchy of labor.

Instruction should therefore neglect no opportunity of drawing attention to the better qualities of heart, mind and conduct, repressing the rise of evil propensities and inculcating sound ideas of trade morale by commenting on examples and facts taken from life.

This is a social duty which should be infinitely extended.

The cultivation of the faculties will also aid in developing the indispensable qualities of goodwill, courage, good sense, etc. —in short, in raising the craft consciousness.

A coherent system of instruction will not confine itself to "storing up" knowledge, but will also aim at forming the mind, tempering the character, and cultivating good taste, self-confidence, enthusiasm, the spirit of initiative and observation—at imparting, in short, all the qualities recognized as being indispensable to the normal and lasting improvement of the individual.

Initiatives to Be Followed

From the foregoing it is not difficult to discern the principal points upon which effort should be brought to bear for the purpose of taking comprehensive measures and carrying them out uniformly and with success.

Let it be said at once that success will be dependent upon common action to be taken by the public authorities, manufacturers and labor organizations.

A sufficient number of instructional institutions will be established or reorganized, due consideration being paid to the liaison which must exist between them, so as to permit of progressive and graduated training from the starting point to the stage of higher instruction. The basis will be apprenticeship served in the works or at the schools.

In foundries employing at least 50 workmen, an apprenticeship school with a special instructor would be established to take 10 per cent of the young men as apprentices. This system, as we have seen, would not necessarily mean a large financial sacrifice to the manufacturer. In certain districts foundries employing a smaller number of workman might make arrangements in common, or else place the apprentices in direct contact with the best skilled workmen, subject, however, to their being under a very special supervision by the foundry foreman so that the syllabus of the apprenticeship shop may be faithfully followed, which will be the easier in view of the small number of workmen employed.

Whenever possible apprenticeship will be served in the schools, provided, however, that the conditions approximate as closely as possible to trade practice, otherwise the vocational equipment acquired will be quite inadequate. Here the workshop-school will be really organized, its work being completed by the period of training in the works themselves.

Complementary to this workshop apprenticeship, elementary groundwork courses for young molders will first be established with the co-operation of the trade, and then evening or Sunday improvement courses, as certain demonstrations cannot be carried out profitably except in the foundry. The general, scientific and technological training courses will be given at the industrial school in the evenings or on Sundays.

As far as possible special foundry sections will be organized by districts in order to insure that these courses shall be well staffed and have suitable teaching equipment and material. Thus the expenditure allowed will be concentrated and will consequently be more productive.

It should be understood that the foundries themselves will be freely open for the technological course, for it will be to its interest in every way to be conducted in the atmosphere of actual

production, since it is there that it will find the best subjects for its demonstrations, and that visits to foundries will be systematically organized.

Higher evening courses will also be established regionally and will take pupils from the special sections of the intermediate industrial schools, the purpose of this organization being the training of foremen.

In the following stage the secondary technical school will be destined to train the intermediate supervisory staff and the higher foundry staff. The members will be supplied by the full time vocational school or by the higher industrial school.

A research and testing laboratory installed with the cooperation of all the Belgian foundrymen, who would entrust it with their work, would usefully complete this institution from the scientific point of view. From top to bottom of this instruction ladder one preoccupation will prevail: to inculcate habits of order, regularity and precision, so as to contribute to the establishment of a method of work which is indispensable in the trade.

I have alluded to the training of the teaching staff and the apprenticeship masters. This question requires to be very carefully studied by the various groups of foundries and the technical foundry associations in conjunction with the public authorities.

A central body incorporated in the Technical Foundry Association might compile and distribute the necessary instructions and data with reference to the qualifications required for teaching foundry work intelligently and successfully.

In order to give a more definite basis to the instruction it would be useful to have prepared standard lessons, with discussions, for use in the teachers' training classes which should be organized.

It is known that the various foundry associations are studying the question of apprenticeship and technical instruction, following the example of the Industrial Committee for Vocational and Technical Instruction, appointed by the Central Industrial Committee of Belgium, to whose work I have frequently referred.

I think it of interest also to cite here the general resolutions adopted by this Committee, whose work, in my opinion, is worthy of great attention:

"The members of the Inquiry Commission entrusted with the compilation of the present report have in addition unanimously adopted the following resolutions:—

"The Industrial Committee for Vocational and Technical Instruction:

"Having taken note of the statements of MM. Ropsy, Léonard, Moens, Varlet, Hiernaux and Dupont, the report of M. Soupart to the Brussels Congress of April 9 and 10, 1927, that of the Technical Foundry Association of Belgium and M. Hublet's letter of April 11, 1927;

"Being impressed with the urgent necessity of reorganizing or supplementing the present methods of training skilled labor and the supervising staff in foundries;

"Being convinced of the advantage which vocational instruction in foundry work can derive from the employment of apprentices in manual labor in the works, which in many cases must continue to be superior to the school's in equipment, however well equipped such schools may be;

"Being of opinion that it is difficult and not a paying proposition for the foundries to employ the services of apprentices between the age of 12 and 13;

"Fearing that the Belgian foundries will contribute only inadequate help to the establishment and active maintenance of Auxiliary Societies for Technical Instruction similar to that recently added to the Ecole des Arts et Metiers in Paris, and this principally from an apprehension of being led to train their labor and their staff by supporting instructional undertakings whose activity is in part commercial and consequently more or less competitive;

"Being convinced that it is a matter of major interest to give theoretical courses of instruction to the future skilled workmen and the future members of the supervising staffs in foundries (French, Flemish in Flanders, drawing, geometry, a knowledge of metals, the technology of the trade, mechanics, the morale of the trade, etc.);

"Recommends:

"1. That the vocational schools be reorganized or developed on principles to be specified according to the particular district of the country, so as to admit children of 12 to 13 years of age who intend to become foundry workers;

"2. That there be provided in these schools:

"(a) Theoretical instruction for the purpose both of completing the general training of the intelligence and character of the apprentices and of giving them the groundwork of the theoretical and scientific instruction upon which must be based the modern practice of that branch of metallurgy hitherto termed foundry work;

"(b) A scheme of practical tasks which shall gradually prepare the apprentices for the manual work of molding and coremaking. The purpose of these tasks shall be simultaneously to direct the apprentices toward work in foundries and to familiarize them with its practice, without necessarily claiming, in view of the necessarily restricted equipment resources

and the limited number of years of training, to turn out a sufficiently complete product to undertake all the manual work done by foundrymen;

"3. That an obligatory stage of 4 to 5 years of practical work in the workshop shall be prescribed between attendance at the vocational school and that of the industrial school. Certain foundries of sufficient size, or groups of foundries, may, if they consider it necessary, institute theoretical courses during this stage and may even establish vocational improvement schools. These would admit young men of 15 or 16 on leaving the vocational schools proper. Their practical training would occupy the greater part of their time (6 to 8 hours a day) to enable them to develop and complete in the foundry the vocational knowledge which they have previously acquired. Under the direct guidance of apprenticeship masters, acting as special monitors, they would be progressively initiated during two or three years into a complete knowledge of the trade. Short theoretical courses (one or two hours a day) would complete the theoretical instruction of the vocational school and would enable those who are most qualified to prepare for staff instruction (foremen and employes entrusted with special branches of management);

"4. To request industrial schools (to be determined regionally) to provide a foundry section in the syllabuses. Evening courses would train young men between 18 and 20 who have good attendance certificates from a vocational improvement school, for the purpose of enabling them to become foremen and special foundry employees;

"5. To establish in Belgium a Higher School of Foundry Work to train chief engineers for foundries, similar to that in Paris."

These resolutions give expression to a most gratifying tendency, for manufacturers are in a position to render the very highest services to technical instruction and consequently to the country.

These associations have a very large field of action before them: the drafting of syllabuses, the compilation of monographs on the trade, the preparation of teaching material and particularly of the technological tables I have mentioned when discussing scientific and technological instruction in the trade.

There is no lack of good foundry handbooks, but most of them are too advanced for the elementary groundwork instruction which I have described.

Could not competitions be advantageously organized by the Technical Foundry Association of Belgium for the purpose of giving our special trade instruction perfectly suitable manuals? These should work out scientifically and technologically the syllabuses in the various stages to which instruction has to be adapted.

Moreover, while technical publications on foundry work are well compiled both in Belgium and abroad, they are not designed either for beginners or for workmen and do not contain studies and explanations suitable to their degree of training.

Motion pictures and lantern-slide lectures also should not be forgotten, particularly for the purpose of showing the best that is being done abroad, for example in connection with machine plant.

The doctrine of vocational and technical instruction in foundry work having thus been sufficiently established, it remains for us to examine briefly certain measures designed to promote it and to ensure its successful application among those interested.

Measures of Propaganda

To improve recruitment it is clearly necessary to take steps to win over parents and young men, and also to interest the primary schools in the trade, by showing clearly the factors governing it and by combating the indifference of the young to this kind of work. I consider that practical results can be obtained by employing the following means:

1. Visits to foundries, foundry schools or vocational courses relating to foundry work, by pupils in the higher forms of primary schools;

2. Motion pictures or lantern-slide propaganda lectures in labor centers and in the schools, in the latter case preferably before visiting the works;

3. Posters exhibited at the end of the school year to attract the attention of parents and of children about to choose a career;

4. Requesting the co-operation, in this connection, of schoolmasters;

5. Forming, in connection with existing courses, propaganda committees composed of representatives of employers' and workers' associations;

6. Issuing at the close of the school year propaganda leaflets in the form recommended and carried out by the Industrial Committee for Vocational and Technical Instruction as a result of the Journée Patronale of September, 1926;

7. The publication of concise monographs on the trade to be distributed effectively;

8. Requesting the co-operation of the trade unions in encouraging apprenticeship and good attendance at the courses in their branches;

9. The institution of students' scholarships to enable promising pupils to begin and prosecute their studies in accordance with the scheme laid down;

10. The organization of a more intimate co-operation between the school and the workshop and between families and the bodies promoting apprenticeship;

11. Posting up prominently in foundries the appeals for attendance issued by the industrial and vocational schools, with a few words of encouragement from the management;

12. Enlisting the co-operation of the local and regional press;

13. Organizing competition in trade work with exhibitions;

14. Giving all desirable ceremony to prize distributions;

Etc.

Finally, in order to attract good men, it is obviously desirable to offer them advantages superior to those in the other metal industries, as it is recognized that a high level of wages is always a powerful attraction.

With a higher level of wages, guarantees of permanent work, as good hygienic conditions as possible and means of moral improvement, etc., the recruitment of labor for the trade will assuredly become easier and be better in quality.

The Functions and Duty of the Trade and the Labor Organizations

There are innumerable ways in which the trade and the labor organizations can give effective and valuable help in the promotion of technical instruction.

Hitherto obligatory vocational instruction has been nonexistent in Belgium, but even when it is legally established the situation will remain the same and will still require such measures as I am urging.

No system of apprenticeship will ever be well organized unless the employers interest themselves in it seriously and help it in every possible way.

Similarly, the labor organizations should, in a fine spirit of energy and perseverance, urge attendance at the schools and should never lose sight of the fundamental importance of this duty, which is the mainspring of the solution of so many problems and conflicts.

The apprenticeship bodies should therefore have the active support of the trade union branches, whose duty it should be to insure that apprentices who leave the schools with sufficient training are adequately paid.

I have noted with pleasure the more general interest displayed nowadays in these questions of instruction by manufacturers. One indication of this in Belgium is the Industrial Committee for Vocational and Technical Instruction, while the work of the Belgian Technical Foundry Association is another.

The influence exerted by such bodies may prove the more effective as it is flexible in its application, and, as it touches those interested directly, its effects may be more rapidly felt than State action, which involves provisions of all kinds which take a long time to organize.

I also recommend the frequent inspection of the training courses by the owners of foundries themselves. Such visits will have the best possible result provided they are made for the purpose of bringing about desirable improvements and giving all possible encouragement.

It would be impossible, moreover, to over-emphasize the necessity for the manufacturer to keep a constant watch over the recruitment of young workmen, selected as carefully as possible and trained in accordance with the principles already described. One of the conditions of success is therefore the faith of the manufacturers, founders and others, in this mission and in the benefits of apprenticeship. Not only must this faith be shared unanimously, but the employers must also instill it into their managing staff, by whom ultimately it will be transmitted directly to the younger workers. It is no less important that this faith shall be honored in the workers' organizations, in order that labor also may participate to the full in the general progress. From the economic point of view is not this of the utmost importance in view of the perfect balance which ought to exist between supply and demand in regard to skilled labor?

By eliminating all possible economic instability, while avoiding the inflation of wages—which has always an undesirable reaction on costs—and by removing the difficulties of all sorts resulting from it, we shall be able to wage the struggle against foreign competition successfully, while at the same time securing a better civic training of the units composing the army of labor —which is surely in itself a sufficiently high and fruitful aim to attract the goodwill of everyone.

Discussion-Session on Steel Metallurgy

W. J. Corbett, presided as Chairman of Session No. 3, which convened at 11:00 a. m., Tuesday, May 15. J. W. Frank presented the paper, General Characteristics of Alloy Steel Castings, reprinted on pages 119 to 128.

Discussion—General Characteristics of Alloy Steel Castings

Chairman W. J. Corbett: Mr. Frank has covered a very wide field in his paper* of the description of the characteristics of alloy steel castings and the Chair wishes to extend thanks to Mr. Frank for his efforts in preparing this descriptive matter.

A. W. Lorenz: I was particularly impressed with the second paragraph of the paper where the author refers to the advertising of steels by fancy names and numbers. I think that is a matter of very serious attention. It is only a short time ago we were asked by a manufacturer to make some alloy castings; it just so happened that we could not do this work and we recommended another firm that had been doing a lot of advertising and who you would think would know alloy steel castings. They prepared these castings and they were put in service and the castings were a distinct failure. This may result in this young concern failing because it had a lot of the machines come back on it.

Now I have never found any formula for steel castings that was as good as the standard alloy type which has been in use for years, and I think the sooner the steel foundry men realize that the better it will be for the whole industry, because it is giving the industry the black eye when castings fail and the users are getting the impression that all castings are no good.

Chairman W. J. Corbett: I think this is a timely warning for us not to get too enthusiastic over alloy castings for purposes for which they are not meant, or for applications where they are not suited.

S. R. Robinson: Can Mr. Frank give the formula for nickel, chrome, molybdenum and carbon for the same strength on normally used air-quenching.

J. W. Frank: Nickel 1.50, chrome 0.75, Molybdenum 0.40 and carbon 0.40.

S. R. Robinson: Do you think you would get the strength without the oil quenching?

J. W. Frank: Yes.

*Editors Note: The author calls attention to certain needed corrections in his paper. Page 121, last paragraph, the first sentence should read, "Nickel steels are one of the best known and oldest of all commercial alloy steels." Page 123, second sentence, the words "railroad knuckles" should read "draft gear knuckles." Page 123, paragraph 3, first line, the word "pots" should read "carbonizing boxes." Page 126, fourth line from bottom of page, the words "railroad knuckles" should read "draft gear knuckles."

S. P. ROCKWELL: With the molybdenum as low as thirty, does that increase the elastic strength of the alloy?

J. W. FRANK: I do not have my data with me; but my recollection is, that it is raised but not in any great proportion.

MAJOR R. A. BULL: I wish to say that Mr. Frank is to be commended for his willingness to give information; that shows a fine spirit that we can all approve. In reading this paper for the first time I had my attention drawn to the second paragraph where Mr. Frank mentions the fact that certain foundries are advertising their product under fancy names and numbers "steels with varying contents of carbon and manganese; which cannot be compared to the real alloy steels, which carry, in addition, nickel, chromium, vanadium and molybdenum." And in the paragraph on Manganese Steel he brings that down to alloys containing as low as one, and one and a half per cent manganese which have not been classified as alloy steel until recently. Mr. Frank makes a distinction between alloy and carbon steels which seems to include steel containing manganese of one to one and a half per cent. Now if we are going to make that distinction in trying to grade steel castings on that basis, if we are going to grade steel with a manganese content of one to one and a half as common grade, I think we are going to make a mistake. Now if we could agree—and I think we could not—that steel from one to one and a half per cent manganese should grade as carbon steel, would it not be better to class all alloys and any grade of steel, without the common grade, into a special grade or class? After all it is not a matter of whether it can be technically classified that the customer or user is interested in. They want to get the physical properties. I don't think Mr. Frank had the intention of reflecting directly, or indirectly on steel with a one to one and a half per cent manganese content, because if he did I would offer to debate that question with him. I think perhaps if a person read this paper hurriedly he might not get the right turn on it, he might take a meaning that Mr. Frank did not intend.

CHAIRMAN W. J. CORBETT: Major Bull has brought up a very important subject in connection with this paper, the grading of the one and one half per cent manganese from the ordinary type of steel.

J. W. FRANK: That particular grade of manganese steel is good, but we have found that other steel alloys are better.

A. C. JONES: In Mr. Frank's paper in the part about molybdenum steel, in the third paragraph he makes the statement: "The uncertainty of results has been troublesome in the past, has been entirely eliminated with improved methods of adding the molybdenum." That is of great interest to me because I have found considerable uncertainty of molybdenum not only in thin steel castings but in rolled bars.

Discussion—Manganese Steel

The paper, Manganese Steel by H. P. Evans and A. F. Burtt was read by Mr. Evans. This will be found on pages 129 to 140.

S. R. Robinson: We have recently heard of a report of a high speed tool steel which is claimed to cut manganese steel commercially. Can Mr. Evans tell us anything about the workability of this steel on manganese steel?

H. P. Evans: I am acquainted with the steel to which you refer. We have used this steel in experimental work and to a limited extent in production. We find it a very excellent steel, one of the best we have used. We have duplicated the results quoted by the manufacturer in their report. On certain types of machine work this steel will operate on manganese steel fairly satisfactorily, possibly on a commercial basis. The cutting speed is very slow. If one has a little job, or a productive job that can be set in the lathe and machined at a low speed, the steel will do the work. If a tool loses its cut in manganese steel, the manganese steel as a result is so hard that it is sometimes impossible to continue cutting. This peculiar hardening was explained in the paper just read.

S. R. Robinson: Do you think it would be practical to use it commercially at the present time?

H. P. Evans: No, not on miscellaneous manganese castings.

S. P. Rockwell: What method do you use to determine the hardness?

H. P. Evans: We use the Brinell.

S. P. Rockwell: Do you find it will give accurate results?

H. P. Evans: In general, yes. Because of the deep indentation caused by the Brinell ball. The Brinell method would not record so accurately a skin hardness that might be caused by cold work.

S. P. Rockwell: Would you say, then, that the hardness does increase on the surface?

H. P. Evans: Yes, it does.

S. P. Rockwell: But does it go up in the Brinell to any extent?

H. P. Evans: Yes, in some cases as high as 400 or more.

S. P. Rockwell: And the body of the casting still remains the same?

H. P. Evans: Yes.

A. C. Jones: Is the manganese held at 14½ per cent or does it run from 13 to 14 per cent?

H. P. Evans: There are only a few types of castings where the manganese might run as high as 14½ per cent. The manganese content of most castings runs from 12 to 13 per cent.

A. W. Lorenz: Can an elasticity of 50,000 to 55,000 pounds per square inch be obtained commercially? I have seen quite a few advertisements in the papers about the elastic limit around those figures, and I was wondering whether such limits could be reached as a steady commercial proposition or whether getting these results were just an occasional occurence.

H. P. Evans: I would not depend on 50,000 to 55,000 all of the time, but the failure to get that limit is not a real failure, if I may so express it. You have a continual sort of sliding which has been mentioned, and, therefore, it is not a sudden failure but a sort of progressive slipping.

Discussion—Heat Treatment of Miscellaneous Steel Castings

The paper next presented was on a Modern Plant for the Heat Treatment of Miscellaneous Steel Castings, written by A. W. Lorenz. This paper will be found reprinted on pages 141 to 152.

Chairman W. J. Corbett: The steel foundrymen are indebted to Mr. Lorenz for this description of a modern plant for heat treating; this matter seems to be of increased importance each year.

S. R. Robinson: Do you water quench everything, or do you use oil sometimes?

A. W. Lorenz: We water quench practically everything. I might say that the temperature of the water is 125 to 150 degrees and we can keep it at that temperature without adjustment. We have a circulating feature. You never want to leave a casting in water until it is cold; we leave it in for a certain length of time and if we have a high alloy, we cut that period rather short. I will say that as far as castings are concerned, one or two a month at the most is all we have ever cracked and they would be castings of new design. Water quenching is not hard on alloy castings. We do run into cracked castings but that is due to the flame cutting of the risers.

S. R. Robinson: Do you use more metal if the casting cracks?

A. W. Lorenz: Yes, we leave more metal, or saw off the risers.

S. R. Robinson: Do you think you can get as good results with water quenching?

A. W. Lorenz: You are probably on the safer side to use oil, as you can leave pieces in the quench for a longer time. Water quenching is a time proposition and requires some experience. We have a small oil tank that is used for special jobs such as finished castings, for instance, and they are better quenched in oil than in water because of greater freedom from distortion.

A Member: Are they drawn immediately after they are quenched?

A. W. Lorenz: Yes, and the castings are perhaps 600 to 700 degrees when they go in the draw.

A Member: What is the carbon content? I know that is a hard question to answer, but about what is the maximum carbon content?

A. W. Lorenz: I cannot say definitely, but we are quenching material up to one per cent of carbon and having no difficulty. They are small pieces and I do not know whether we could quench such steel in large sections. I have in mind some little pins that are about two inches in diameter and we quench them for about a minute, possibly two

minutes, but actually you can leave them in until they are cold. I do not think we need to have any fear of water quenching.

S. P. ROCKWELL: Have you allowed them to cool down to just above Ar_3 to prevent distortion?

A. W. LORENZ: No, we have not done that. One of the things that causes distortion in water quenching is the time quenching; in that case you are taking the casting out before the whole body of the casting is the same temperature. Of course in unfinished castings that does not make any difference.

S. P. ROCKWELL: You can take the finished castings and by raising the heat to or slightly above Ac_3 then cooling down to a safe factor and above Ar_3 and quench. You will find the oil hardening steel may be water quenched without fear of crackage or undue warpage.

A. W. LORENZ: That would be worth while. Can this be done commercially?

S. P. ROCKWELL: By removing from a high-heat furnace held at or slightly above Ac_3 to a low heat furnace held at a safe factor above Ar_3 and equalizing before quenching.

E. R. YOUNG: In your quenching operation; do you separate your castings?

A. W. LORENZ: We handle three different types of alloy castings, on which we have established three standard quenching temperatures, namely, 1450°, 1500°, and 1550°. These temperatures are about fifty degrees lower than the recommended temperatures for such steels, due to our ability to maintain close control over all our operations.

E. R. YOUNG: Do you recommend annealing of all castings before quenching?

A. W. LORENZ: It would take more time to separate the castings than to put them all through the same process. Everything goes into the foundry annealers before being heat treated.

E. R. YOUNG: But do you believe annealing is necessary?

A. W. LORENZ: Yes, in order to relieve casting strains, and in case of castings requiring machine work to soften them for machining and prevent distortion.

H. P. EVANS: Do you do the same with the manganese castings?

A. W. LORENZ: I believe they ought to be treated the same.

Report of Committee on Heat-Treatment of Ferrous Metals

To the Members of The American Foundrymen's Association:

Your committee was originally organized to co-operate in a joint capacity with a sub-committee of A. S. T. M. Committee A-4 to develop a Recommended Practice for the Heat-Treatment of Steel Castings. This practice has now existed as standard since 1924, requiring no further action from your committee up to the present time.

At our 1927 annual meeting, your committee reported the favorable action of A. S. T. M. Committee A-4 with respect to the sub-committee report on "Definitions of Terms Relating to Heat-Treatment." This work has now been issued by the A. S. T. M. under the title "Tentative Definitions of Terms Relating to Heat-Treatment Operations," Serial Designation A119-27 T.

Your committee has during the year attempted to obtain expression of opinion from our members as to a suitable term to recommend in the above "Definitions" to cover ordinary furnace-cooled annealing as practiced in the foundry trade. The entire lack of response to our appeals would indicate that the members of our Association are satisfied to leave this to the discretion of the A. S. T. M. committee.

During the year, the American Society for Steel Treating has issued a set of data sheets* on the Heat-Treatment of Carbon Steel Castings, and is about to issue further data sheets on the heat-treatment of certain common types of alloy castings. The A. F. A. as a body has no representation in this work, although the A. S. S. T. Committee is constituted largely of foundry interests. We are advised that these Data Sheets are to be considered as informative only, and not as a specified practice. They are issued in their present form to invite criticism and discussion, and will be subject to modification from time to time.

*Tentative Recommended Practice for the Heat Treatment of Carbon Steel Castings (Nov., 1927); American Society for Steel Treating, Cleveland.

The A. S. S. T. Data Sheets on Heat Treatment of Carbon Steel Castings differ from A. S. T. M. Standard A36-24 in that they enter into more detail. They also include a section on the latest developments in high-temperature annealing, and recommendations for the casting of test coupons which are not found in the A. S. T. M. Specifications.

It is the recommendation of your committee that our members make themselves acquainted with the above A. S. S. T. Data Sheets on Recommended Practice for the Heat-Treatment of Carbon Steel Castings, and that all criticisms should be forwarded to J. E. Donnellan, Secretary Recommended Practice Committee, American Society for Steel Treating.

Respectfully submitted,

A. W. LORENZ, *Chairman;*
E. TOUCEDA,
J. F. HARPER.

Discussion–Session on Steel Founding

W. J. Corbett, presided as Chairman of Session No. 12 on Steel Founding. The session convened at 2:00 p. m. on Wednesday, May 16.

H. A. Mason presented the paper, Reducing New Sand Consumption in a Steel Foundry. The discussion of this paper follows:

Discussion—Reducing New Sand Consumption in a Steel Foundry

E. R. Young: With regard to the average grain size of your recovered sand, I notice that the finest grain is 35 mesh at 30° angle. About what grain size sand does that give you?

H. A. Mason: It gives us a sand about 12 per cent of which will pass through a 60 mesh screen.

J. H. Herron: I notice Mr. Mason speaks of refractoriness of clay. Is he referring to the fusion point or the vitrification point? I have often been presented with that question—which is the vitrification point or the fusion point?

H. A. Mason: I think that the point about which we are most concerned is the vitrification point of the clay. We feel that clay scale, which is made up of vitrified sand and clay, is unfit for use and we throw that part of our sand away. It is removed by the top screen of our reclaimer. In one case I notice we have quoted the fusion point of clay A as 2,800 degrees and that of clay B as 2,950 degrees. A high fusion point of course does not mean very much if the clay vitrifies at a lower temperature. We have found that in the case of clay B the vitrification temperature follows very closely the fusion point; in other words, the amount of vitrified sand and clay which we have to remove is reduced to a minimum.

David Evans: Mr. Mason shows Grade A clay and Grade B clay. Does that mean two different brands of clay or types of clay, or what sort of clay is it?

H. A. Mason: Two different types of clay. Type A is a comparatively cheap fat, colloidal clay, which as I stated the Bureau of Standards places near the top range of average foundry clays, while clay B is a hard, lean clay with a fusion point of 2950°. Clay A has a fusion point of 2800°. Clay A is an Ohio clay and B is a western Pennsylvania clay.

E. R. Young: What was your regular mix in regard to the percentage of new sand before you started reclaiming the sand?

H. A. Mason: Before we installed the reclaiming unit we used an all new sand facing on all patterns and for nearly all cores. At the present time our No. 1 facing is made up of 50 per cent new sand and 50 per cent reclaimed sand. In the No. 1 facing and in oil sand cores all the new sand necessary to keep the supply on hand constant is added, which in our case

amounts to 300 lbs. per ton of good castings for both the foundry and the core room. Putting it another way, we have just reversed the process in that we use only as much new sand as we have to use to make up the amount which is thrown away, while before we used as much new sand as we thought was necessary to insure good castings.

N. T. Booth: Somewhere in the paper I saw something about the drying of this sand but in the illustration of the Plan View Sand Reclaiming System on page 558, I don't see any drying unit.

H. A. Mason: The drying was only done in the experimental work. In the day to day practice the sand which comes down on the flogging floor is dried by the hot castings and is put into the reclaimer.

N. T. Booth: You are able to get sufficient drying of green sand molds by the heat of the castings so that you do not have to do any drying before passing over the screens—is that correct?

H. A. Mason: Yes. We cannot put wet sand through our screens. That is absolutely prohibited because the screens would clog up. I might say that we regulate our sand from our reclaimer by screen tests. When our screen tests show that we are getting more than 10 or 12 per cent fines which will pass through a 60 mesh screen, we clean the screens, using a wire brush.

H. T. Preston: In removing this fine material, have you ever run into the trouble with metal penetration of the sand.

H. A. Mason: None.

H. T. Preston: I have run into that myself several times, inasmuch as it seemed by using a dust arrester and a few finer screens, we removed the fine material which resulted in a penetration of metal on casting, and we had to use silicon flour to hold the sand up to produce a smooth casting.

H. A. Mason: In other words, you had too great a permeability, is that it?

H. T. Preston: The permeability was about 150.

H. A. Mason: That's about what our sand runs but we have no trouble with metal penetration.

E. R. Young: I would like to suggest that the answer to that is probably the size of the metal section. I infer Mr. Mason's company runs a relatively thin section, and Mr. Preston probably refers to heavy dry sands.

H. T. Preston: Our work was green sand—all our dry sand work was silica washed and this showed up in green sand with castings of 100 to 500 pounds, and about an inch to 2 inch sections; mostly in rail joint work castings, about an inch section.

M. D. Pugh: Have you ever tried sand which is of a grade to pass less than 10 or 12 per cent through a 60 mesh to see what happened?

H. A. Mason: Yes, we have tried that but our experience has shown that is is not necessary, at least on our class of work, to reduce the fines very much below 10 or 12 per cent. The larger amount of sand removed increases the amount of new sand which must be added.

R. S. MUNSON: I would like to ask Mr. Mason if after screening his sand he noticed any particular difference in the amount of clay coating on the grains of sand. I would like to know if after bonding your sand this way, taking it through the screen, if most of the clay is removed from the grains or if a large amount of it remains.

H. A. MASON: Using clay B a large amount of clay still remains on the grains of sand, and we have found that this is good plastic material, which still retains its strength. We use Simpson type sand mixers in our foundry which in the mulling action completely coats the grains of sand with clay. We retain about 7 per cent of good plastic clay in the sand which comes from the reclaimer, we add about 10 per cent in all new sand facing, therefore we lose approximately 3 per cent of clay in the reclaiming operation. Our facing sand mixtures are therefore brought up to the required strength by the addition of 3 per cent of clay. Since starting the use of clay B, we have only had to add clay to our heap sand at rare intervals. The clay which we add in the facing sand passes on into the heap sand and maintains the required strength which in our case is 1 to 1.3 lbs. per square inch.

R. S. MUNSON: Is clay B commonly known as flint clay?

H. A. MASON: No, clay B is not a flint clay but is a clay which combines the two essential qualities of a high grade clay, a high fusion point and high bonding power.

The paper by Mr. Mason was followed by the paper by K. V. Wheeler on The Interdependence of Operating and Sales Departments in the Success of a Foundry. The paper by Mr. Wheeler will be found on pages 651 to 659, inclusive.

Report of A. F. A. Representative on Joint Committee on the Investigation of Phosphorus and Sulphur in Steel

To the Members of the American Foundrymen's Association:

Your representative on the Joint Committee on the Investigation of the Effects of Phosphorus and Sulphur in Steel presents the following report of the activities of this Committee, since the 1927 A. F. A. Convention, in so far as they relate to the product of the steel foundry. The Committee's activities generally are regularly announced at the Conventions of the American Society for Testing Materials, preliminary to a complete resumé which may be issued subsequently.

It may be advisable as a reminder, to give the names of the organizations that have taken part in this joint investigation which was started in 1919. These organizations are as follows:

American Foundrymen's Association
American Railway Association, Mechanical Division
American Society for Testing Materials
Association of American Steel Manufacturers
National Research Council
Society of Automotive Engineers
Society of Naval Architects and Marine Engineers
Steel Founders' Society of America
U. S. Bureau of Standards
U. S. Navy Department
U. S. War Department

It will be recalled that it was originally the idea to investigate the influence of sulphur in steel castings as in other steel products; that after much work had been done it was reported officially by the Committee that no deleterious effects of sulphur within amounts up to .06 per cent were established in commercial rivet steels; that no deleterious effects of sulphur within amounts up

to .077 per cent were established in commercial plate steels; and that the tests on these two classes of steels were embraced in the most comprehensive program that has ever been conducted to ascertain the influence of a chemical element on a steel product. For the reason just given, and because the Joint Committee's personnel consists of 16 individuals representing 11 organizations of national character, the conclusions announced by the Joint Committee are regarded as authoritative.

It will also be recalled, as previously announced to A. F. A. members, that the Joint Committee decided to omit that item of its program calling for tests to ascertain the effects of sulphur in steel castings, because of recommendations made by representative foundrymen who were influenced by the results of the rivet and plate steel tests, and who felt that due to the red-shortness caused by a high sulphur content, a research to determine the effects of sulphur in steel castings would have academic rather than practical value. It is well to remember that the objects of the entire investigation are to determine the influence of phosphorus and sulphur under service conditions only, and have no bearing on difficulties of manufacture, except as these are known to be related to serviceability.

The Joint Committee decided to have the cast steel tested for phosphorus made in an acid open hearth furnace because it is from that type of furnace that the largest tonnages of steel castings for miscellaneous purposes are produced. Care was taken in the selection of a plant for manufacture where advisable safeguards would be provided. In accordance with a well arranged plan, during the week of September 11, 1927, at the foundry of the Atlantic Steel Castings Company, Chester, Pa., eight special heats of acid open hearth steel were made, from which were cast 288 bars required for the laboratory tests and for reserve material that may be used subsequently by the Committee. The bars were poured in the presence of delegated representatives of the Committee, including the Secretary-Manager of the Steel Founders' Society of America, and the undersigned.

Efforts were made to eliminate every controllable variable factor. The heats of seven and one-half tons each were produced from pig-iron and carefully selected scrap containing very low percentages of phosphorus and sulphur. Iron pyrites and ferro-phosphorus were added to the bath approximately one and

one-half hours before tapping to provide the desired contents of sulphur and phosphorus.

Open top molds having feeding blocks 4 inches thick above 6 ribs 12 inches long and 1⅛ inches square, made from a mixture of pure silica sand bonded with fire clay and molasses water, were jar rammed, each with 100 jolts, then thoroughly oven dried.

The chemical analyses as desired and as obtained are shown in Table 1.

Table 1

ACTUAL AND DESIRED CHEMICAL ANALYSES

Heat No.	Actual Carbon	Desired Carbon	Actual Mn.	Desired Mn.	Actual Si.	Desired Si.	Actual Phos.	Desired Phos.	Actual Sul.	Desired Sul.
					Class A					
1275	0.28		0.78		0.39		0.034	0.025	0.043	
1279	0.30		0.73		0.33		0.042	0.040	0.042	
1282	0.29	0.25	0.83	0.70	0.32	0.35	0.063	0.060	0.047	0.045
1284	0.28		0.60		0.33		0.070	0.070	0.045	
1281	0.26		0.75		0.36		0.093	0.100	0.044	
					Class B					
1277	0.48		0.78		0.39		0.037	0.025	0.051	
1276	0.48	0.45	0.70	0.70		0.35	0.050	0.050	0.042	0.045
1280	0.47		0.72		0.37		0.065	0.070	0.044	

At the U. S. Bureau of Standards the bars were given the heat treatments as prescribed in the following program that had been prepared after careful consideration:

Heat Treatments

1.—*Annealing.*

0.25 per cent carbon steel.

Hold at 1650 degrees Fahr. for two hours and cool in furnace without opening door. Permissible to open few small vents in top of furnace to allow escape of heat.

0.45 per cent carbon steel.

Hold at 1600 degrees Fahr. for two hours using same procedure as for 0.25 per cent carbon steel.

2.—*Normalizing.*

0.25 per cent carbon steel.

Hold at 1650 degrees Fahr. for 2 hours and withdraw from furnace while at this temperature, each bar to be quickly placed to one side away from contact with other bars and on same surface which is at room temperature; all for the purpose of providing the same cooling operation for each side of every bar and give it a true normalizing treatment.

0.45 per cent carbon steel.

Hold at 1600 degrees Fahr. for 2 hours and use same procedure as for 0.25 per cent carbon steels.

3. *Normalizing and Drawing.*

0.25 per cent carbon steel.

Hold at 1650 degrees Fahr. for 2 hours. Withdraw from furnace to cool as described above for normalizing. Reheat to 1150 degrees Fahr. and hold at this temperature for 3½ hours and cool in furnace.

0.45 per cent carbon steel.

Hold at 1600 degrees Fahr. for 2 hours. Withdraw from furnace to cool as for the 0.25 per cent carbon steel. Reheat to 1250 degrees Fahr. and hold at this temperature for 3½ hours and furnace cool.

In all heat treatments, bars to be heated gradually to the temperatures recommended. No restriction as to rate of heating.

The test material has been heat treated and shipped to the Watertown Arsenal and the Naval Engineering Experiment Station at Annapolis for machining and testing, it being the procedure of the Joint Committee to have check or duplicate tests made at these two laboratories for verification of results. Insufficient time has elapsed since the receipt of the heat treated test material at these two Government stations to permit preliminary announcement at this time regarding the results of the physical tests, for hardness, fatigue, compression, tension, torsion, and impact, all at normal temperatures. A large amount of work is required for machining the specimens, and this work must be done without interfering with activities of greater immediate significance to the Government. It is hoped that by the time of the 1929 A. F. A. Convention complete information concerning the tests of the cast steel material may be publicly announced.

The expense of making the experimental foundry steels was defrayed from a fund obtained by individual contributions solicited by the A. F. A. and by a contribution from the Steel Founders' Society of America. All told, 110 steel casting companies shared in absorbing this expense, thereby giving gratifying evidence of the keen interest taken by steel casting producers in this co-operative investigation. The total collections received by the Treasurer of the A. F. A. for financing this work amounted to $1,010.00. The Association's expenditures amounted to $742.61, leaving a balance on hand of $267.39, the disposition of which is to be decided after the receipt of requested communi-

cations on the subject from those who contributed to the A. F. A. special fund. It was agreed in advance that the company considerately offering its facilities for the manufacture of this material should be reimbursed for all the direct expense involved. The sum of $742.61 expended from the A. F. A. special fund includes half of the amount paid the Atlantic Steel Castings Company to reimburse it, the other half having been paid by the Steel Founders' Society of America, according to its original proposal as made to the A. F. A., with which Association the Steel Founders' Society has co-operated in this entire investigation in the heartiest spirit.

Your representative will be pleased to have suggestions or instructions at any time concerning his representation of the interests of the A. F. A. steel foundrymen on this Joint Committee, in whose deliberations he is of course expected to express opinions concerning suitable tests for all the classes of materials being studied. While your representative considers it unnecessary through himself to report on those phases of the investigational work that do not directly relate to steel castings, he believes all manufacturers and users of ferrous materials should give careful consideration to every report on behalf of the Joint Committee through the medium of the A. S. T. M. and otherwise, partly because of what your representative regards as the probable relationship between the influences of phosphorus and sulphur in steel castings and the influences of those elements on other steel products having chemical compositions that do not obviously place themselves in such different categories as to make comparisons unscientific.

It may be stated finally that the work of the Joint Committee has made considerable progress in testing to determine the influence of sulphur. The steel foundry tests are the first of those actually started by the Joint Committee to ascertain the influence of phosphorus.

Respectfully submitted,

R. A. Bull, *A. F. A. Representative*

On Joint Committee on Investigation of Effects of Phosphorus and Sulphur in Steel.

Discussion—Oxy-Acetylene Cutting of Risers

J. Fletcher Harper presided at session No. 6 on Steel Founding, held at 10:00 a. m., May 16. The first paper presented at this session, Economies in Oxy-Acecylene Cutting for Riser Removing by G. O. Carter, will be found on pages 377 to 384, inclusive.

S. R. Robinson: Mr. Carter, what is the competition of acetylene as against carbo-hydrogen in cutting, and secondly, city gas at moderately high pressure?

G. O. Carter: That question can best be answered by giving a little of the history of the use of the cutting processes. About 6 years ago there was ended an era of keen competition between various fuel gases used in the cutting operation. At that time it was a common practice to have torch operators of the various supply companies meet almost weekly in regular gladiatorial contests. The results were not impressive. A great deal was left to the judgment of the operator—it necessarily had to be—as to the size of tip and the gas pressures he was going to use. If he guessed right, he made a wonderful cut; if he guessed wrong, the results were, maybe, double in time and gases used than would be the case if he had guessed right.

The following method was evolved and was used in two or three cases, and since then there has been practically no competition. The operator, representing one interest, would be permitted to work with the user's man to see that he was getting the proper performance out of the equipment and the gases that were represented by that particular organization. The competitor's operator would have the same privilege, records being kept by both. Then, seeing that the user of the cutting process is the most interested party, it was up to him to run the test over a long enough period to eliminate serious variables. Anywhere from 3 days to a week's results indicated that the oxy-acetylene process had nothing to fear from any of the other competitive processes.

N. R. Knox: As to this magnetic mechanical cutting machine mentioned, how is it attached to an uneven surface and what thickness of metal will it cut?

G. O. Carter: It will handle practically any thickness of metal, the thicker probably the better, on the economic side. It has magnets that are slightly pointed toward each other, so that it would attach to a riser. It can be hitched to any electrical circuit where you have magnets. It will hold itself strongly enough so that it will pick up a riser. As I remember, we had two pretty husky men jump onto a riser bar that was being held by such magnets, and they couldn't jump it off.

A MEMBER: Mr. Carter, could you give us some reasons for not using acetylene in over 15 pound pressures?

G. O. CARTER: Acetylene has been used at higher pressures and found hazardous, because acetylene is one gas that changes its characteristics with increasing pressure to the extent that it will detonate with extreme violence. That occurs at some point above 17 pounds gauge pressure. It very seldom will occur under 20 pounds pressure. When you get up towards 30 pounds, given the right conditions, it will detonate every time. The fact that it never will detonate below 17 pounds points a way to the safe handling of it, and that is to keep the pressure below 15 pounds. That way to handle it was determined many years ago by the National Board of Fire Underwriters. Wherever operating men keep within that pressure they have no troubles from that characteristic of acetylene. This is not the so-called popping back of the torch, the back-firing. It is an entirely different thing, and when it does occur at the higher pressures, it is usually disruptive. Now all throuh our industry the equipment that complies with the Underwriters' Laboratory requirements and the N. F. P. A. requirements is limited with safety precautions to 15 pounds.

There is no other gas known that has that characteristic of acetylene but it is that very characteristic that gives acetylene its energy, which comes to you in the hottest flame that is known. The two things seem to go together.

Report of the Committee on Steel Castings

To the Members of the American Foundrymen's Association:

Last June your committee appealed to you for support in a controversy regarding certain points in a specification proposed by a committee of the American Society for Testing Materials for steel valves and fittings for high temperature service. You responded in gratifying numbers and we are glad to report that at the general meeting of the American Society for Testing Materials in French Lick last June the objectionable changes were withdrawn and the specifications left as they had been, and as we wished them to be; the points at issue being referred back to the proper committee for further consideration and recommendations.

Since then, while a special committee was being formed to consider these controversial points, an attempt was made, informally, to reach a basis of compromise, but owing to the development of certain opposition the attempt did not then succeed. So at meetings of the American Society for Testing Materials committees held in March of this year, it was voted to refer these points back to the proper committees for further consideration, and the matter stands just where it did a year ago. We hope that a final settlement may be reached this coming year, one that will be acceptable to both sides.

To us, your committee, the most gratifying features of the entire matter have been the evidences of interest you have shown and the enthusiastic support you have accorded us.

Approving:

A. H. Jameson, *Chairman,*
J. H. Hall,
L. Uhler.

Not Approving:

R. A. Bull.

Discussion

The report of the Committee on Steel Castings, after being presented by the Committee Chairman, A. H. Jameson, was discussed at length, the discussion revolving about the Committee's standpoint in regard to the proposed A. S. T. M. Tentative Specifications A-95 for Carbon Steel Castings for Valves, Flanges and Fittings for High Temperature Service. Following the discussion Mr. Jameson moved the adoption of the following resolution for forwarding to the Board of Directors,* for transmitting to the A.S.T.M.

RESOLVED: *That in the opinion of those present, changes proposed at the informal conference in Cleveland, participated in by Messrs. Bull, White, Spring, and Warwick, as a basis of settlement of the much discussed process and chemical limits clauses in A. S. T. M. Specification A-95-26T are not satisfactory.*

That the process clause proposed is not acceptable due to its discrimination against two accepted processes without supporting evidence.

That they are also opposed in principle to the inclusion of chemical limits other than for phosphorus and sulphur in specifications where physical limits are specified.

The motion was seconded and carried, sixteen members present voting.

*The resolution was presented to the Board of Directors at its meeting on July 16, 1928. It was the consensus of opinion that the attendance at the meeting at the time the resolution was voted on was not sufficiently representative of the members interested in these specifications to justify action by the Board and on motion the report was laid on the table.

Discussion–Variables in Steel Foundry Practice

J. Fletcher Harper presided as chairman of Session No. 6 on Steel Founding. The paper by F. A. Melmoth, presented at this meeting, will be found on pages 323 to 358, inclusive.

Chairman J. Fletcher Harper: Since 1921 the A. F. A. has been exchanging papers with the Institute of British Foundrymen. It has been the pleasure of this organization at various times to hear valuable contributions from our British cousins on this exchange. Today we have the honor of hearing the fourteenth of these exchange papers, presented by F. A. Melmoth, who is the manager of the Steel Foundry of Thos. Firth and Sons, Ltd., of Sheffield, England. Mr. Melmoth is not present but he has a very able assistant, or rather, I should say relative in this country who is going to present his paper. It, therefore, gives me pleasure to introduce George Batty, of the Steel Castings Development Bureau, who will present Mr. Melmoth's paper, "Variables in Steel Foundry Practice."

Mr. Batty then presented an abstract of Mr. Melmoth's paper.

Chairman J. F. Harper: Gentlemen, you have listened to the presentation of a very valuable paper, covering a large number of variables in the steel foundry practice, and I am sure that Mr. Batty will be very glad to answer such questions as he is capable of, and the Society and Mr. Batty will transmit all your discussion to Mr. Melmoth for his full approval and answers.

Major R. A. Bull: We are very much indebted to Mr. Melmoth for this contribution and to Mr. Batty for coming here and giving this presentation of Mr. Melmoth's paper. For several years I have been a greatly interested reader of Mr. Melmoth's papers contributed to the Institute of British Foundrymen and other organizations on the other side.

I have been particularly interested to note the observations that Mr. Melmoth has made from time to time on porosity, on deoxidation, on the influence of moisture, and many other problems with which I am confronted in my regular work, and with which many of my acquaintances and friends are familiar. I have always felt that Mr. Melmoth had a very sound understanding of those problems. I think his contribution to our discussion today emphasizes that.

Among other items in the paper that must be interesting to us are his views on the influence of sulphur and phosphorus. Apparently the view held in steel foundry circles in England corresponds very closely to that now obtaining in this country with respect to the maximum permissible percentage of sulphur, specifically 0.06 per cent. I see, too, that Mr. Melmoth is quite liberal, as some regard it, in his views in reference to the

influence of phosphorus, which is something which we have not determined so definitely as we have the influence of sulphur through the activities of the joint committee on the investigation of phosphorus and sulphur in steel. It is extremely interesting and valuable to have this interchange of opinions and experiences along these lines.

S. R. Robinson: I would like to ask Mr. Batty if he will give us a little more explanation of the tarring of the molds. That is something, little known in this country.

Geo. Batty: It is a fairly common practice in Great Britain on very heavy work, using the "composition" that Melmoth wrote about, to tar the molds after they are withdrawn from the drying ovens and while they are still hot. It is rather important that boiled tar or hot tar should be used, and the molds (and cores, also treated in a similar way), should be hot, to ensure driving off the volatiles of the tar absorbed by mold or core. The mold or core may then be put back in the oven and given a further period of drying.

The actual carbon increment to the casting after such treatment is very small indeed, and yet the surface of the casting is exceptionally good, much better than one normally gets with a mold faced with silica wash, which is apt to spall off, under the influence of radiant heat, above the metal that rises in the mold, and so produce a dirty casting. With the tarring you have a slightly repellant action on the metal as it rises in the mold, with the result that any small erosions of sand or mold material are carried forward up into the risers and you get much cleaner castings; also the castings are much more easy to clean, than under the ordinary mold conditions. There is less burning on and there seems to be a definite sealing of the surface of the mold and an elimination of the tendency of the metal to fuse the refractory material that forms the mold.

The one point to remember is that you must not leave readily volatilizable matter on the surface of your mold or on your core. If the mold as tarred is not very hot, or if the core as tarred is not very hot, put it back in the oven and drive off the lighter constituents of the tar. Then you will get extraordinary good results, as compared with ordinary practice. The mold is not silica washed before being put in the oven, as a general rule. In the case of very coarse molding material, such as is used on heavy castings, you may apply a silica wash before drying and the tar after that, but, as a general rule, with the fairly fine constitution of your facing material your mold absorptive power is limited and you are able to do away with the silica wash and just use tar.

Major R. A. Bull: Mr. Batty do you know of any experiments of a comprehensive nature that have been conducted abroad to find a satisfactory substitute for aluminum, in what we might call a harmless deoxidizer? I mean for use in pouring say, fairly low carbon steel (which I agree is more inclined to porosity than high carbon steel) of very hot temperature, which is shanked into molds of thin sections, and where, in other words, the tendency to porosity is the maximum—are any experiments

being made to discover a material or to develop a material that will have substantially the same influence in protection against porosity and at the same time will not influence the ductility injuriously. Some companies in this country have spent quite a lot of time and effort in the attempt to do that sort of thing, but I believe it is a fair statement, that if there is a thoroughly good substitute for aluminum under the conditions that I speak of, anyone who knows it is keeping the information under his hat. There have been a good many deoxidizing compounds, quite a number of them made abroad, and some of them sold to a greater or less extent in this country, but unfortunately, nobody seems to have discovered just what we are all looking for. I am sure that there must be, at least considerable curiosity, if not commercial concern with respect to that matter on the other side.

GEO. BATTY: My experience has been, and I think I also speak for Melmoth, is that so far there has not been discovered and put into commercial use an efficient substitute for aluminum, but I am going to amplify that statement by saying that in the majority of cases I object most strongly to the method in which aluminum is introduced to the steel. Take the case of small steel castings which are poured from a hand shank:—the usual practice is to throw into the handshank a piece of aluminum. You get the metal going onto that, and your aluminum is brought to the surface, sprayed over the surface and oxidized. You have alumina produced there. Probably the whole of your aluminum is converted to alumina before that metal enters the mold. Really the function of the aluminum is to deal with any incidental oxidation in the mold during pouring. Therefore, you must have your aluminum in solution in your steel in order that it may function in that particular manner. When you get steel going into a mold mixed with alumina present you are likely to get into trouble, and a good deal of trouble.

The aluminum is introduced to deal, with the incidental oxidation that the steel runs up against in the mold, the splitting up of steam, and an oxidizing gas being produced, which gives a pronounced tendency to porosity. If there is aluminum in solution in your steel it is competent immediately to deal with that immigrant gas, or with the gas that is trapped within the steel itself, and then your inclusions in light steel castings will be very small and will not be really very deleterious in producing low ductilities; but when you pour steel plus alumina into a mold, you have an entirely different condition. My practice was to have the aluminum made into blocks with a hole through the block, and the block was sawed off to the requisite amount. I have used as low as 6 ounces to a ton of basic electric steel. The whole of the steel and the slag, too, go in the ladle and then the aluminum is introduced. This is plunged to the bottom of the ladle, so that you are likely to get a solution of aluminum in your steel, which will then be competent to take care of any incidental oxidation in the mold.

So far as other deoxidizers are concerned, I have not found them competent to take care of incidental oxidation nor of the pin-hole trouble, which is a very prevalent thing on light steel castings.

The main trouble that Melmoth had—I didn't have it to anything like the same extent—he attributed to the rather high silicon in some of his basic electric steels. He came to the conclusion that 0.35 to 0.40 per cent silicon was the maximum allowable for basic electric steels, if they are to be reasonably free from porosity. I can't say that Melmoth and I agree entirely on the matter of over-reduction and the presence of dissolved oxide being essential to fluidity. I will have to ask you to divorce Melmoth's ideas entirely from mine on this matter until I get his sanction to say that he agrees with me. At the present time he won't go so far as I go, but his contention is that with high silicon introduced into the steel from the "basic" slag, primarily due to fluxing of the acid roof and walls of the basic furnace, the constitution of the steel is essentially different. We are very apt to regard steel on the conventional analysis, which takes no accurate cognizance of constitution. A conventional analysis merely defines composition, not constitution. That's where Melmoth draws the distinction, that basic steel with silicon introduced from slag, silicon in an atomic condition, that is, gives him an entirely different steel with respect to gas absorption. Such a steel, containing 0.35 to 0.40 per cent silicon largely introduced from the slag in an atomic condition, is badly over-reduced and appears capable of absorbing gases from the mold while still liquid. Therefore, you will get a very bad blown condition and a pronounced tendency to amplify the ordinary bad condition that arises from chills (due to much more absorption than is a normal blow from chills) with over-reduced steel containing silicon introduced from slag, than you will have with a normal silicon introduced from ferro-silicon. I have purposely over-reduced basic electric steel and reduced silicon from the slag and have gotten these bad results, confirming Melmoth's results, but then when I have taken any steel and treated it normally in a basic electric furnace to give me my normal fluidity, that is, avoided over-reduction, I have introduced as much as 0.5 or 0.6 per cent silicon from ferro-silicon and have had non-deleterious results. We, therefore, both associate this bad feature with rather high silicon in basic steels, introduced from the slag. There's the reservation—we both associate it with the fact that the silicon is introduced in an atomic condition, not as an alloy, and, therefore, this gives the steel entirely different properties, different from what one would expect by comparing the two steels of an identical composition, as revealed by ordinary analysis. On the question of over-reduction, my opinion is that silicon introduced from the slag appears competent to produce an abnormally sluggish condition in metal obviously hot, and I have attempted to associate this peculiar condition with the elimination of what I have considered to be the normal equilibric oxygen content of the metal.

It has been proved repeatedly that when this over-reduced, or sluggish, condition has occurred in the steel in the furnace, as revealed by

the examination of spoon samples, it can be corrected by a small addition of any form of oxide of iron to the slag or to the steel. I feel sure that Melmoth agrees very largely with the opinions I hold on this question of dissolved oxide; in fact, it was originally his assertion that this abnormal sluggishness which occasionally occurs in mild steels for castings might be attributable to the elimination of some final vestiges of oxide which are normally contained in steels made by the converter and open hearth processes. He is not prepared to be dogmatic on this point, but my feeling is that there is so much evidence to indicate that a very small proportion of oxygen has a significant effect upon the fluidity of low carbon steel for castings. Steel which has been over-reduced and which has been reverted to normal fluidity by the addition of a small amount of oxide in the furnace does not—let me be quite definite on this point—does not produce castings vitiated by blow holes. In fact, it appears to be considerably less prone to the pin-hole trouble that is somewhat prevalent in making light steel castings in green sand molds.

While I prefer to think that the matter solely hinges on the question of the small amount of oxygen, which I consider to be the equilibric oxygen, in solution in the steel, Melmoth seems to prefer the viewpoint that a high silicon, largely introduced from the slag in the atomic condition, is responsible for the deficiency manifested by the metal.

A. W. Lorenz: I believe Mr. Batty's statements regarding the method of the addition of aluminum are well taken, and that possibly if the aluminum is added early enough and in a proper manner we won't have the difficulty of getting proper ductility from our steel. My point is that we are now able to obtain ferro-aluminum, which can be added in the furnace, and you use no more ferro-aluminum than you would of pure aluminum, regardless of the fact that there is only about 40 per cent of aluminum in the ferro mixture. It is also very reasonable in cost, and I am anxious to know whether any of the others here have tried ferro-aluminum—adding it in the furnace instead of in the ladle.

Major R. A. Bull: I know of one concern that has just started to experiment with that material, but the work hasn't gone far enough to enable them to reach any tentative conclusions yet. It seems to have a good many things in its favor, one of them being, I think, the specific gravity of the material. For instance, in adding it in shank, it does not have a tendency to float on the top of the surface and in other ways detract from its possible beneficial results.

In speaking about this matter of aluminum, it occurs to me to make just this comment. Occasionally we hear—as I heard at the last Annual Meeting of the American Society for Steel Treating—a gentleman announce his conviction that to make good cast steel it is very undesirable to use aluminum. I heard that statement made by a man who is connected with a prominent steel foundry. Well, that kind of a broad statement doesn't get very far, if you will permit me to say so, when one is talking to men who are making castings that are particularly susceptible to porosity. Whenever a man makes a statement that it is

entirely unnecessary and injudicious to use aluminum, I want to know what he is making, and to know if he is making small castings from steel that must be very fluid, reasonably low in carbon, and pouring them in green sand molds, shanking the metal. I would like to see that done without using aluminum.

A. W. LORENZ: I wasn't present at the meeting but I sent in a written discussion in which I advocated the elimination of aluminum, if possible. I qualified my remarks by stating in what cases we did not use aluminum. We make both basic open hearth steel and acid electric steel, and our basic open hearth steel naturally goes into our larger castings. Those castings are poured in dry sand molds. Wherever you use dry sand molds you use no aluminum and you get good sound castings, but where you use green sand molds you have to use aluminum. I thought Major Bull was referring to me and that he hadn't gotten the whole story, and I wanted to set him straight.

MAJOR R. A. BULL: I wasn't talking about Mr. Lorenz. I was talking about a man from Duquesne who read a paper. In the discussion he was very emphatic in his statements about this. Now the qualifications which Mr. Lorenz made, which he has just mentioned, are quite important. There is no question at all about the fact that the thorough dryness of the mold caused by oven treatment is a very, very important matter and retards the possible formation of pin-holes in castings, as anyone who makes a few experiments can find out for himself. We all know that for the great majority of our castings green sand is the logical material to use for many reasons, and that we have to make from commercial and other standpoints many castings in green sand. Where you have a percentage of moisture in the mold, which might vary from 2 per cent to 5 or 8 per cent, there is certainly the tendency to form porosity. The safeguards that Mr. Lorenz has in mind, in selecting the type of molds in which to use aluminum, and the other safeguards that have been mentioned as to the manner of introduction, are all extremely significant.

W. E. GRIFFITHS: I would like to make a statement in regard to the use of aluminum in making steel. I don't speak from my own experience because I am not a steel man, but I am acquainted with a gentleman who has made steel for perhaps 25 years and I might say who is connected with one of the largest steel companies in the country, and it is his thought not to use any more aluminum than you absolutely have to. I don't believe myself that aluminum is the best thing in the world for a deoxidizer in steel. A gentleman here asked the question a short time ago if in England they had any deoxidizer which could take its place. I would suggest that in this country certain foundries find it very beneficial to use zirconium, silicon and zirconium and they find the cost of silicon alloy is not a great deal more expensive than the straight silicon alloy when the zirconium content is low. This zirconium not only acts as a scavenger, particularly in its effect on oxygen and nitrogen, but it also has a very valuable property in distributing sulphur throughout the casting. I am sorry I don't have here this morning some sulphur prints

to show the valuable effect of zirconium in distributing sulphur throughout the cross section of the casting. It is quite evident from an examination of sulphur prints of this kind that the sulphur is evenly distributed.

The other statement that was made, I believe—I don't know whether it was interpreted correctly or not—was with respect to the use of aluminum and green sand castings. I would like to ask the question whether the gentleman hopes to scavenge the gases, the moisture and oxygen that combine with iron and produce oxide in the mold, that is formed during the pouring by the addition of aluminum. I should think myself that aluminum that takes up oxide or oxygen would be trapped within the casting and form oxides which are not desirable.

F. A. Lorenz, Jr.: It seems to me in this discussion that we are getting a little bit off the track. There are four types of steel being discussed here, basic open hearth, acid open hearth, basic electric and acid electric. I think any of the men dealing with them will find that there are different characteristics in each one. In our acid open hearth practice we feel that if we properly make the steel in the furnace the use of aluminum is unncessary, and it is only when the steel is improperly made that we do find the use of aluminum necessary. I cannot speak for the electric process as I am not entirely familiar with that, but we do make acid steel that does not need aluminum, and we make it continually. Now the feeling in our plant is that if steel is properly made in the furnace the use of a deoxidizer is not at all necessary.

F. J. Crane: I have been away from the steel end of the game for a good many years, but I have been on the electric furnace for probably 24 or 25 years. For the last 13 or 14 years I have been dealing with high nickel chromes, but from previous experience with aluminum I have known many cases where, as the last gentleman said, steel if properly made in the furnace requires very little aluminum. I can remember when I first went into the steel business, about 26 or 27 years ago, that my father said never to make steel in the ladle but make it right in the furnace. I always followed that practice. As far as introducing aluminum into a furnace, I have always introduced aluminum in a 3 inch pipe on the end of a rod, and I regulated that by taking what we call a set test. A set test is used altogether on nickel, especially the high nickels, such as 60 nickel, 20 chrome, or 80 nickel, 20 chrome. That same test can refer right back to steel. I could see whether I had over deoxidized the steel or not by the amount of the set. You watch the set test. It sets in the iron mold about an inch and a half in diameter and about 5 inches high. Your first set test of steel you take out after you have melted it. I am speaking now of basic, not of acid, because the acid requires little or no aluminum at all if properly made, and the proper temperature carried in the furnace. If that test rose on the first one from a two ton heat we used to introduce about 14 or 15 ounces of aluminum and let it work probably 6 or 7 minutes before we took the next test out, keeping our voltage not too high, around the 90's on the heat. The general principle was, and is today in the steel business, that if it is near

5 o'clock at night and the fellow on the furnace wants to get home he doesn't have any regard for the poor molder or foreman down in the shop who has got a lot of green sand rammed waiting for the steel to come down—he throws in 5, 6 or 8 pounds of aluminum, because nobody knows about it—he has probably stolen it from the storehouse. I think from all the discussion I have heard here as to aluminum being used, that if more attention and care were referred back to the furnace by the man taking care of that heat, that you would find in time that there would be little or no aluminum used in the making of steel. As to Major Bull's question about a harmless deoxidizer, I am just giving you some information on my practice on high nickel chromes and on high nickels. I don't know whether this would work out on steel or not. On high nickels we can use pure magnesium, which we do use to a certain extent, but as we go into nickel chrome magnesium is too violent, it blows all over. Mind you, it is added in the furnace, not in the ladle. We make nothing in the ladle. I wouldn't throw an old pair of shoes into the ladle because I know they wouldn't do any good. Speaking now of the lowest grade that I make, which is 20 nickel, 10 chrome—if I were to use a pure magnesium in the furnace the violence would be so great I would be afraid it would blow the roof off the furnace, so we have purchased a silicon magnesium, made up into sticks in preference to the powdered form. That runs practically about 40 per cent magnesium and 60 per cent silicon. We put this into small cans and introduce that into the bath by having it wired onto a long rod underneath the slide. The violence by this method is not so great. This might be worth trying out for steel. I believe that in the electric furnace the slag contains all the oxides and when you raise that electric furnace up a certain amount of slag gets in with the first part of the steel and boils it, and the first thing you know you have oxide back in the metal. So I carry my tap hole on the electric furnace way below the slag line. Before I tap it I raise the furnace probably a foot at the back, and we tap it the same way that we used to tap the acid open hearth many years ago, with a dolly bar in the back, and when it starts up we bring the furnace up, and we get first all the steel and the slag comes last. I believe that if the steel is poured out of an electric furnace, especially the basic, and tapped the same way as I state, this aluminum question would be brought down to a minimum.

Chairman J. F. Harper: I sincerely hope that Mr. Melmoth will not get an opinion of American steel as all being poor, as some slight comments have been made here in regard to aluminum and its use. He very clearly states in his paper, "all the materials, while representing useful special additions to steel, are in no way capable of nullifying the effects of poor steelmaking practice." I would hate in any way to have it returned to England that American steel practice is all poor, because I don't believe that that is so, and I sincerely hope that the weight being placed with this aluminum question will not be misinterpreted.

Geo. Batty: Going over the remarks of the last three or four speakers I would like it to be understood, and I think Major Bull will agree

with me, that this steel for green sand castings, if poured into dry molds without any addition of aluminum, would make perfectly satisfactory castings, free from blow holes. The introduction of a small amount of aluminum for green sand castings is to take care of the incidental oxidation of steel. The steel is perfectly good as it goes into the mold but is subject to attack by immigrant gases, which in certain circumstances it can absorb, the circumstances being high temperature and, as Melmouth points out, an abnormal silicon content. That's one point that must be appreciated, otherwise we will have no common ground for discussion. This steel, as steel, is perfectly sound and can safely be poured into certain green sand molds; but under extraordinary circumstances, high temperatures, large exposure or inordinate superficial area in relation to mass, you have there pin-hole penetration—you have immigrant gases from the mold, and you must have something there that is competent to take care of the gas that comes in. That gas is very largely air, or steam—steam probably split up—and you must have something there to take care immediately of that immigrant gas. Now, it may either be aluminum, it may be an alloy of aluminum and magnesium, which was also used and discontinued because it is no more efficient and a good deal more expensive, it may be silicon and zirconium, but in each case we have a solid product of reaction.

And this is in reply to Mr. Griffiths with regard to zirconium and silicon. The products of deoxidation must be solid, just as in the case of aluminum. In one case you have alumina and in the other case you have zirconia.

With regard to your sulphur prints, I can't speak authoritatively on this matter but I am going to suggest that your sulphur prints may prove quite a lot or nothing. For instance, take high speed steel containing a fair amount of chromium and tungsten; you may have 0.15 per cent sulphur in that steel, and if you were to take a sulphur print of that and show it to anyone they would say, "Wonderful steel, there is no sulphur there;" yet an analysis will reveal 0.15 per cent sulphur. That is purely a suggestion not derogatory in any way, purely a suggestion to explain your supposed diffusion of sulphur. The diffusion effect, of itself, may be valuable.

With regard to ferro-aluminum, we haven't tried that yet. We, in the Steel Castings Development Bureau, intend to try it. The whole point here is, when you are going to put aluminum into steel, the aluminum goes into the mold for the purpose of taking care of any immigrant gases or oxidation incidental to pouring into that mold, and the aluminum must exist in the steel, as it enters the mold, as aluminum—not as alumina. With careless addition of aluminum in the handshank your steel is incapable of performing its correct function, as there would be no free aluminum there—or insufficient aluminum, to deal with the gases absorbed incidental to pouring into the green sand molds.

W. E. Griffiths: In regard to the sulphur prints, I would say that the sulphur prints I speak of were made on three individual heats made in the same furnace, one after another, and of the same composition as

near as is possible to obtain it by regular practice. The one heat was made without any zirconium addition and the other two heats were made with zirconium additions, and it was quite evident, the difference in the sulphur distribution with respect to the formation of aluminum oxide or zirconium oxide, or whatever product of oxidation is formed. I might suggest that the volume of the products will probably be less in the case of zirconium than it is in the case of aluminum.

GEO. BATTY: That is quite possible, sir. My suggestion with regard to your sulphur print is that zirconium may have the same effect in relation to sulphur as has tungsten or chromium, in that there is little, or none, of the reaction which gives you the color on your print which identifies your sulphur. That is purely a point in passing and not really significant or relative to the present paper.

L. W. SPRING: I would like to ask Mr. Batty's slant on the effect of high residual manganese and silicon in steel as opposed to the oreing down of the steel, to throw off the silicon; to oxidize the silicon and manganese before building up, particularly with reference to the electric furnace, of course, and especially with respect to the bend test.

GEO. BATTY: My practice is to see every heat boil. I have a conviction that when you are using, as part of your charge, steel scrap from your foundry, you are introducing some very, very finely divided silica, and that silica of itself will not levitate sufficiently rapidly to be freed from the steel, whereas when you introduce oxide of iron you get a component which conforms with the formula, I believe, $2FeO.SiO_2$, which readily levitates to the surface. Therefore, I invariably make it a practice of seeing the heat boil. My experience has led me to assume that it is unsafe to melt a heat out at the carbon content desirable and not have the heat boil, and my experience with the bend test on such a charge as that specified is that it is better with a boiled heat than it is with an unboiled heat. The silicon-manganese elimination is one which takes place at low temperatures in an electric furnace. If the practice is to use dirty scrap, oxidized scrap, you will get an automatic boil once the essential temperature of reaction is reached and, consequently you are getting out, to a very large extent, any of your fine silica inclusions that otherwise would be there from your foundry scrap.

When we speak of residual silicon we must be perfectly sure that it is entirely residual silicon, that it is not silicon that has been re-introduced from the slag. That means we have to take samples of the charge for analysis before it is melted and samples throughout the heat to see where the silicon actually goes down to. We had some rather remarkable results in Detroit on that at the Detroit Steel Castings Company plant. We got a low temperature reaction and the silicon was eliminated down to 0.03 per cent. Then we got a building up of silicon from the slag. This self-reduction of the steel, either in the basic or acid electric furnace—not so much in acid as in basic—promotes an over-reduced condition of steel, which is deleterious. You rob the steel of its equilibric

oxygen content, that is our theory; it has not yet been proven, but we hope to prove it some time in the future. In reply to your question, I would say that I do consider it advisable that every heat in the acid or basic electric furnace should boil; if you are using base materials in your charge they are likely to be contaminated with fine silica.

Author's Written Reply to Discussion of Paper Variables in Steel Foundry Practice

F. A. Melmoth: There are a few points brought out in the discussion calling for comment, and I propose, therefore, to take them in the order reported, and endeavor to give a personal reply.

In the first place, the complimentary remarks of Major Bull are fully appreciated, and it is gratifying to learn that one's work is sympathetically followed by such an authority.

The problems enumerated, viz., porosity, its relation to de-oxidation and mold influence, are surely the very essence of the practical metallurgy of the steel casting. With our generally improved steel making knowledge, we can very easily meet all present day physical requirements, but can we, with equal certainty, forecast and arrange for the production of the perfect cast free from defects, due to incidental influences? I feel that we have not yet reached this desirable point, and therefore our exact knowledge falls short of what is required. Pure metallurgy is unlikely to solve these problems for us, as the troubles experienced are largely extraneous to the actual facts of metal production. By this, I do not intend to convey that research in steel manufacture cannot assist us. There is an almost virgin field to explore along the line of the possibilities of producing metal in such a condition as to be less susceptible to extraneous influences. For instance, we feel that the presence of manganese can, and does, afford some additional security. We also feel that in green sand molds, the actual presence of small amounts of aluminum always, be it understood, assuming the steel to be in perfect condition before its addition, increases the degree of security. Why, then, should we stop at this point? Certain other additions, or even some process variation, may be even more efficient in reducing the degree of susceptibility of our steel.

With regard to sulphur and phosphorus, I am forced to the opinion by experience alone, that when present in the usual small quantities, their effect is smaller than is sometimes believed, and in the production of casting defects, certainly of a much less deleterious nature than that of a whole host of mechanical contributions to a bad casting.

I would not wish that there should be read into this statement any toleration for such slack steel practice as would permit their presence in appreciable quantities. Their ill effect is so well known as to be elementary when this is the case.

With regard to Mr. Robinson's question, referring to tarring, Mr. Batty has answered this very fully. I would add that the method is largely a question of personal practice. Good results are obtained every day on fairly

heavy work without its use, while in other shops, it represents standard practice. The precautions mentioned by Mr. Batty are vital, otherwise the state of the mold or core is worse afterwards than before.

Major Bull's second contribution to the discussion raises an interesting point, viz., the probable use of de-oxidizers other than aluminum. We do feel, of course, that the use of the latter material always involves the possibility of non-metallic inclusions, and its excessive use is undoubtedly bad practice on this account, if on no other. What we need, as steel founders, is, of course, a de-oxidizer, which either produces an oxide soluble and harmless to steel, or which produces such a fluid oxide, that it frees itself very easily from the metal during solidification. Various materials have been used, but, so far, as I am aware, they all produce oxides of a deleterious nature if present in appreciable quantities. Calcium, alloys of silicon, aluminum and manganese, and to a certain extent, ferro-titanium, have all been used with the purpose to eliminate the use of aluminum.

They all, however, possess drawbacks in varying degree. I feel that I appreciate what Major Bull is looking for, and can only say that no experience of mine would lead me to believe that it is in existence at the present moment as part of any foundry practice. Its discovery would rank as a marked step forward along the line of metallurgical progress I have previously mentioned as possible, in the direction of the susceptibility of our steels. With Mr. Batty's strictures on careless addition of aluminum, I am in full agreement. The bulk of the addition is often uselessly lost.

The next portion of the discussion hinges entirely on the use of aluminum. In response to the chairman, I am very unlikely to form any unfortunate opinion as to American steel making methods on the basis of the interest taken in the use of de-oxidizers. It is a question of proportion. All steel makers of sound experience refuse to tolerate the use of aluminum as an even partial substitute for what constitutes good practice. It is not an essential, and I will go further, it is not even advisable for the production of sound steel. Its use in the foundry, always strictly limited, is entirely called for owing to the conditions imposed on good steel by sand molds, which after all, are, at their best, but poor receptacles for the perfect and gas free solidification of steel. When green, contact is made with immense volumes of liberated vapor, and quite naturally absorption is liable to result. The great bulk of high class steels normally made and cast in chill molds does not need any further precaution than good furnace practice. I would also go so far as to say that, even in the case of a green sand mold, the same remark would apply, assuming that the mold was so constituted that instant egress of the produced vapor was possible.

Discussion–Malleable Cast Iron

The session on Malleable Cast Iron was held at 10:00 a. m. on May 16. F. M. Robbins presided. The first paper presented, was that by R. A. Greene, on Reducing Scrap in the Malleable Foundry. This paper appears on pages 513 to 524, inclusive.

Discussion—Reducing Scrap in the Malleable Foundry

W. M. Marr: Our plant is not a large plant; we only operate one furnace, melting about thirty-eight tons a day. Mr. Greene's figures show the reduction of our losses. Our costs for castings in the hard iron state run somewhere about five cents a pound, and the difference between hard iron castings and hard iron scrap is plus four cents a pound, so that you can see the figure for losses runs into dollars.

I do not know of any one thing in connection with foundry operation, at least in our organization, where we can save more money than by close attention to the performance of the molding. We have a high coring cost on our work, a lot of coring work, and there is a lot of money invested in the casting by the time it gets through the plant. To emphasize this point we must get the facts on losses before the molders and instructors as soon as possible, and this is done within twenty-four hours after the molds are poured off. We have this record close to the foundry where we can get at it, and we look at it and study it.

One particular case I can cite is indicative of what can happen in a foundry and which will pass unnoticed unless you have some manner of getting the scrap loss before you. There was a particular condition in that pattern which was a heavy job. We had a good molder, but for some reason he could not make it. We carried him three or four days, and finally had to take it away and give it to another molder, who brought the loss group down immediately. We could have let the first man run along to try to get that job loss down, but he just could not do it; the answer was to let somebody else do it, and that was accomplished.

D. MacIntosh: How many different patterns do you have?

W. M. Marr: About fifteen hundred.

W. C. Missimer: I would like to ask Mr. Greene whether the individual molder receives any financial premium for a low scrap loss, or is that bonus confined entirely to the three inspectors?

R. A. Greene: That bonus is confined to the three inspectors, and a molder receives no premium for a low scrap loss.

W. C. Missimer: You just work on a system of rivalry between molders as estimated by the information shown on the chart?

R. A. Greene: Yes, sir, but he gets penalized for castings that are lost.

Mr. Kelly: How do you handle cracked castings?

R. A. Greene: Cracked castings come under the head of broken castings and are charged to the foundry, not to the molder. Yes, a cracked casting is charged to the inspector. It goes in his bonus.

Mr. Kelly: It seems impossible for a cracked casting to be charged that way.

R. A. Greene: The inspector must use care; the breaking off of the casting is under his inspection. He must be careful that the breaking of the gates do not crack the castings.

D. MacIntosh: Is there no charge made to your core shop for castings cracked by hard cores?

R. A. Greene: No, sir, there is a column on the sheet showing castings spoiled by cores. If that happens to be a figure which we consider too high, we go after the core department. It all comes up in this Saturday morning meeting, but there is no charge made against the core department.

W. M. Marr: I might add that if you look for all the reasons why castings can be lost and the excuses for scrap castings, you can find an awful lot of them. The assumption in this whole thing is that everybody is interested in a certain way and the inspectors are interested as well as the company, in the production of good castings. We sort of put the responsibility for losses on all—with the idea of getting them down. We have obtained the desired results. As to whose fault it might be, it does not matter so much unless, as we get action in producing, we want to know whether it is core trouble or cracked castings that is causing the loss. The idea is that if you have such conditions, it is going to come to somebody's attention right away, and then we will get some action.

L. C. Wilson: Do you find that in the scrapping of castings, any one particular cause predominates?

R. A. Greene: Yes, I think that the biggest loss is caused by a lot of dirt.

R. E. Belt: On page 521 there is shown a reduction in loss of four and a half per cent, attributed, I take it, to this careful watchfulness over their scrap losses. I wonder if you have converted that into dollars and cents and could give us the reduction in loss per ton that has resulted through that reduction in scrap loss?

R. A. Greene: The labor cost, that is, the molding, coring, trimming, etc., runs between four and five cents a pound. We do not lose the metal because we melt that over. That labor cost includes the overhead. If that casting passes the inspector, it is worth that much more to the company.

D. MacIntosh: We want to credit ourselves again with the scrap returned, but we cannot credit ourselves with over fifteen or seventeen dollars a ton, for we can buy scrap for sixteen or seventeen dollars a ton. The difference would be our loss from taking back our hard castings from the furnace.

R. A. Greene: That is so, but this four or five cents a pound does not include that; you have to add that.

D. MacIntosh: I am talking of the metal loss alone; say our metal costs us in the ladle two cents a pound; that is forty dollars a ton; we could only credit ourselves with our bad castings at sixteen or seventeen dollars a ton; the difference would be twenty-three dollars loss per ton on all scrap returned to the furnace.

J. H. Lansing: Do you have the molders go over the castings once a day and are bad casting laid out so that the molders can see them and the inspectors take up the losses with the men?

W. M. Marr: Yes, every day, sometimes in the afternoon. The scrap is sorted and put into display for the sheet. This is about two hours after the heat. All the castings are sorted over and the bad ones are picked out and the instructor uses them as object lessons. The instructor starts out to show that molder what is happening and what the trouble is.

Discussion—An Incentive Bonus Plan for Molders

The next paper presented, An Incentive Bonus Plan for Molders Based on Scrap Control, by R. J. Teetor, will be found on pages 660 to 664, inclusive.

R. J. Teetor: I would like to reply to Mr. Belt's discussion very briefly. The fact is that the operation of this bonus system, or perhaps I should say double pay system, has greatly increased our tonnage per man. We have limited floor space now and have had for sometime, practically every floor being in use. It was very important that we increase our tonnage per man in order to come out on the right side of the ledger, so the first effort was to increase production. Scrap was an after consideration, although a very important one. We did increase our production per man by a very appreciable amount.

I might say further that while the plan described in my paper seems to have worked fairly well in our foundry, it might not work out so well in other foundries, for the reason that we probably had a little different condition to meet. Our foundry was established only six years ago, and established in a district where there were no molders; we had to make them all.

We had a condition there that possibly not many of you have ever been called upon to meet, which was convincing men that the foundry should work, convincing them that a furnace could melt iron and convincing them that a hundred melts a day could be made. They did not believe we could do any of these things, and we actually had to take the first year and more to prove these things to the men we trained. Even now some of the labor that we have to break in is skeptical, notwithstanding the fact that they see other people doing these things. They are more skeptical in our district of the possibility of doing what we ask them than they are in an average foundry center. For that reason it might be that all the features of our scheme might not seem applicable to the average foundry, although they were to us.

J. H. LANSING: There are some cases where that method might show an indirect saving. For instance in a foundry that is paying for cleaning up the floors and cutting sand at so much per floor. There you will get a greater production per floor and the amount you pay per floor won't be any greater than a case of a smaller production. Another case is if you pay your men so much for pouring the iron per floor, it is a floor rather than a tonnage basis. The same thing is true in cleaning up the floors and taking the castings to the hard iron department. It is also true that it will have a certain effect on your tonnage rate going through your shop. If you have a greater percentage of castings from any one pattern going through, your tonnage rate can be slightly lower than if you have a lower percentage. I think those are factors that will differ in various shops, but if these are true in the plant in question, it will show an indirect saving, even though the molding rate is made higher by this plan.

MR. McNEIL: Was any revision in the piece rate made when the bonus was installed?

R. J. TEETOR: No, we paid the same price.

MR. McNEIL: How do you equalize the more difficult jobs? Does not that discriminate against the good molders to whom you necessarily have to give the hard jobs?

R. J. TEETOR: As I said in my paper, when we find an obvious error on the wrong side, that is against the molder, we correct it; against ourselves, we do not correct it unless we find some way of actually improving the job so that the molder has no complaint about a reduction in piece rate. Of course, in our business, we are constantly making new patterns and putting them in production. This gives us an opportunity to establish the rate on the right basis.

D. MACINTOSH: The author says in his paper that eleven per cent represents the molding cost. What percentage is that of the total cost of production?

R. J. TEETOR: That was what I meant, Mr. MacIntosh. Our molding cost is eleven per cent of our total cost.

E. E. GRIEST: Has any one here had any experience with some of these wage payment plans, such as the Maynard or the Badeau system?

J. W. COLLIS: I am not familiar with the Badeau or Maynard systems, but our Detroit plant of the United States Aluminum Company has been using the Parkhurst system for about fifteen years.

This is a plan by which we pay a bonus as an incentive to all the workman, including molders, coremakers, grinders, and other classes of labor in addition to the regular hourly rate.

All operations are timed with a stop watch and we arrive at a standard time for each operation. The bonus is paid according to the efficiency shown on a chart issued for each operation.

We go into the market and hire laborers and molders at the going rate, and they earn that rate unless they earn a bonus. We would not

keep a fellow unless he could "hit the ball," or at least make the 80 per cent figure, where the bonus starts. Our standard times are made to fit the average man and not the speed artist. Occasionally we have a man who will run 120 per cent.

If a man were to make an efficiency equal to 79 per cent, which is 1 per cent below where the bonus begins, he would only have earned his day rate; and his earning divided by the number of pieces he has made gives us a certain price per piece. If in turn a man has made 100 per cent efficiency, he would have earned a bonus, and if the number of pieces he produced at this figure were divided into the day rate plus the bonus the man earned, the piece price would be less. We have made a saving in the price per piece and the man has made an increase in his pay.

Discussion—Oxidation Phenomena During Annealing of Malleable Cast Iron

The paper, Oxidation Phenomena During Annealing of Malleable Cast Iron, presented by H. A. Schwartz, appears on pages 385 to 396, inclusive. The discussion follows:

H. A. Schwartz: The reason for presenting something which, in print, looks like rather abstruse physical chemistry, is very briefly this: a great many of us know, as Mr. Touceda has pointed it out to us, that the machinability of the casting depends very largely upon the machinability of its surface, since in general, machine operations are surface operations and not deep machine operations from the body of heavy sections. That means that the condition of the surface of malleable castings is of the utmost importance. I think we need not emphasize what happens when we get a very deeply carburized rim in trying to cut pure iron. We know the machine shop does not like it very well. We need not emphasize what happens when we get the picture frame which is a case of steel around malleable iron. The machine shops do not like that, either, and so, I take the occasion of presenting a paper here to invite attention to why these things happen, not why they happen specifically, in the sense that somebody did wrong or that the furnace worked poorly, but why they happen as a matter of technical reasoning, and also to bring to the attention of a group of this kind the work of certain research workers, notable Rudolph Schenck, in Germany, upon whose laboratory investigations the actual data of the paper depends.

You all know quite plainly that if you hold a piece of red hot iron in the air, it covers itself with oxide. You may not know, although you can find out by trying, that if you hold it while red hot in carbon dioxide, the product of the complete combustion of fuel in the air, it also covers itself with iron oxide. You do know that if you hold it in carbon monoxide, as in some case hardening operations, you have a deposit of carbon and get case hardening. You know that carbon monoxide, acting on ore in a blast furnace, makes iron out of iron ore. The question is to determine what are the relations between the gas composition in which we treat castings and the resulting surface. That is all summarized on page 387, figure 2, of the preprint, and that is the only one of the figures to which I will have occasion to refer orally.

It may be of a little interest to you to know that the working out of that diagram occupied Dr. Schenck twenty-five years, and that he had the assistance, off and on. of well over twenty research assistants while he

did it. The work was largely financed by an institution in Germany somewhat analogous to the Engineering Foundation here, by grants of money, in the interest of furthering certain industries.

Dr. Schenck made a number of false starts in the twenty-five years, some of which were contradictory to known experience, and he felt around. I do not say that disparagingly. He made many efforts to reconcile his work to the facts.

A few years ago, at the Syracuse meeting of our Association, Dr. Anson Hayes pointed out certain phenomena which were a contradiction of Schenck's work. In my judgment, the pointing out of that contradiction was the greatest service Dr. Hayes rendered in that particular paper, because it focused attention upon the fact that there was some scientific interest in the possibilities of the original diagram. Professor Schenck meanwhile had corrected that error for himself but that correction had not been published.

On the diagram shown on page 387 are certain lines which represent the equilibrium between carbon monoxide and carbon dioxide, and carbon and iron. If we take pure iron and hold it in carbon monoxide, unless we carburize, nothing happens. There is a line on the diagram marked Fe_3C. Whenever we have carbon monoxide, in concentration falling above or to the left of that line, iron carbides will form from iron and a mixture of CO and CO_2. If we are below and to the right, the iron carbides will give us carbon to be converted into iron and either CO or CO_2. Similarly the line marked C represents the equilibrium between carbon and mixtures of CO and CO_2.

Now we come in the case of the compounds of oxygen and iron, to somewhat more complicated conditions. Then let us take ferrous oxide—maybe there isn't any ferrous oxide but I mean the substance we have all called ferrous oxide in the past—and act upon it with a mixture of CO and CO_2. If the CO is more than a certain percentage, the iron oxide will be reduced to iron. If it is greater than a certain percentage and there is present any free iron, the reaction will go backwards, the iron will become ferrous oxide.

Notice the line which in my figure separates the field marked oxo-austenite from the field marked Wüstite, which are two names Schenck assigned to the phases that occur in those particular compositions. If there is a mixture of iron and iron oxide in a composition of gas in relation to temperatures, that line shows that neither will the iron go to iron oxide nor will the iron oxide go to iron. Now, applying that for the moment to the malleable business; in the first place, perhaps we do not want to take any carbon out of the surface of the casting; that may depend on the purpose for which our castings are intended. For instance, for the best machinability, it would be very nice not to remove any carbon. We can do that, at least in principle, if we do our annealing in a gas whose position falls, in relation to temperature, above and to the left of that Fe_3C line. There would be no carburization, although there might

be a deposit of carbon. If we could go exactly on that line, there would be no change in the composition. After we get free carbon, we might burn free carbon.. The compositions which would burn our free carbon are shown by the C line.

Then we arrive at the thought that we do not want a casting scaled with iron oxide; you lose the weight and the casting looks terrible, and if you leave it on it is a messy job to machine it. Also, it is evident that we cannot have any annealing furnace gas whose composition goes below this line if which we spoke just now, the upper boundary of the Wüstite field, because if we do, we will have scaled castings. If we first work in that field and later on something happens, a change of temperature or of composition in the direction of a more reducing gas, we will reduce the layer of iron oxide back to metallic iron which will not adhere to the casting. Then you get the skinning of castings which the Europeans encounter more than we do because they work under more oxidizing conditions, but which you do see in American castings now and then.

Now that is, in brief, the gist of the longer presentation which I have written, the thought being that what you have to have is control of the furnace gas in the direction in which you want to go toward the furtherance or suppression of decarburization. You do not want to get a rim reduced in carbon to the point where you do not have white cast iron any more, nor do you want to reach the point where you have a steel and graphitization is retarded. You do not want so much oxidation that you get iron oxide instead of iron.

How do you control these points? Since the beginning of our annealing practice, you have packed in all kinds of packing which ultimately are silicates of iron. The silicates of iron were used just because we knew they worked. The reason they worked is because the silicates of iron are in equilibrium with gas compositions which have a high enough percentage of CO so as not to oxidize iron. The silicate is merely a balance wheel which adjusts the gas composition automatically to concentrations which will remove carbon; that is, they will combine oxygen with carbon, but not with iron or, in other words, they fall into that oxoferrite and oxoaustenite field at the top of the diagram (page 387), between the Fe_3C and the C line and the upper boundary of that field. Now that is not supposition, although the theory was not known twelve or fifteen years ago. We studied a great many of those silicates, and it is a fact that by measuring the equilibria that exists, they do come out in that direction richer in CO than when in equilibria with carbon; poorer than with iron oxide; and that is, in brief, the physical chemistry answer to the rim question and the decarbonizing question of castings.

Chairman F. M. Robbins: It is indeed a pleasure to have one whose depth of research has enabled him to speak as only Mr. Schwartz can, in presenting his paper before our Association. In connection with the opening of the discussion, we have asked Mr. Bean, president of the Grindle Fuel Equipment Company, to open the discussion on this paper.

W. R. BEAN: I do not know that I can add anything very tangible to Mr. Schwartz' discussion of his own paper. The subject is one which has interested me for many years and on which much work has been done by those who assisted me while I was with the Eastern Malleable Iron Company. The practical application of the theory is, in my estimation, one of the most important items for consideration in the whole malleable industry today. The question of machining malleable castings is always to the front in the automobile industry, and in every industry where a light finished cut is taken followed by operations of threading, milling, and turning. In the supplying of malleable castings, the question which comes first is; how is the casting going to machine? For many years the thought has been with us that annealing was of vastly greater importance to the machinability of malleable iron than the original composition of the metal itself. It is of considerable satisfaction to me personally to have the matter brought out as it has been, because it was so difficult for me to get the idea across to those who had different ideas on the question. I think that there is much that can be accomplished. There is, however, in the accomplishment of that, a real practical difficulty of controlling the character of gases in an oven and in the pots in which the castings are packed.

At least ten years ago we discarded all scale packing and have used instead the fine silicate base for our packing material. Another thing is uniformity of flame conditions within an oven, and in that connection we know how difficult it is with any hand fired fuel to maintain even an approximately uniform flame. We have many times in years past carburized castings purposely to prove our assertion that a great deal of difficulty came from light deposits of cementite in the exterior surface, due to this improper flame and packing condition. A thing that I might suggest in this connection is that the application of pulverized coal firing to the annealing process will be helpful in maintaining a uniform flame condition and that that condition, coupled with the proper packing, will help to bring out castings which will not cause machining difficulty.

J. H. LANSING: The question of packing has been mentioned several times in this discussion, and I think it would be very interesting if Mr. Schwartz would care to say what he has experienced or what he believes with regard to the relative value of the use of packing or the use of no packing.

H. A. SCHWARTZ: Leaving out the question that some castings have to be packed to keep them from warping. I am very doubtful whether there is any utility whatever in packing. Packing will be useful if you are unable to keep the castings in a controlled atmosphere in any other way. If you are able to keep them in a controlled atmosphere otherwise, as, for instance, with a very carefully sealed pot or a muffle with an atmosphere maintained in it, well and good. If you can control it very largely by sealing the pot, the thing that happens then is, in the very beginning, the casting will scale, but at the same time a litle carbon will come off and

it won't be long before that carbon has produced enough CO and CO_2 to stop any further action. We have annealed considerable tonnage without packing, and are annealing more now than ever before. A brick structure in not sealable, as far as I know. We operate a kiln in the same city where we operate an office building, and we measured flows of air through the walls of the kiln, and it flows through faster than through the ventilating system of the office building.

H. W. HIGHRITER: Would it not be a natural conclusion to Mr. Schwartz' paper if, in view of the advantages of iron silicates as to automatically controlling the gaseous atmosphere, to use an annealing packing which, in the first place, was iron silicate instead of one which would become so through use? In other words, would not a slag packing be better than sand packing with such iron as comes from scaling off the top?

H. A. SCHWARTZ: I think that is quite true; air furnace slag is a very good starting point. In going through the furnace, you will get silicate whether you want it or not, but if you are making your own silicate, don't put too much oxide in as raw material at any one time. We all know that the scheme of putting in pig iron borings tends to reduce scaling. It works beautifully for the first or second time, but after that the pig iron has become oxidized and the action reverses itself. If you must have a reducing agent, put in coke and the oxygen will go away and won't leave any oxide to work backwards on you.

MR. KELLY: We operate a baffle furnace firing with natural gas and oil and I would ask if the amount of temper carbon in the gases has any bearing on machinability. We run as low as one hundred and ninety-five carbon, and the castings packed in pots will machine well at high speed. We have a certain kind of a casting, like automobile castings, that are annealed in a brick muffler. There is a slight difference in machining between the castings that are packed in pots and the ones that are annealed in a brick muffler.

H. A. SCHWARTZ: What is in your pots?

MR. KELLY: Nothing except the castings.

H. A. SCHWARTZ: Of course, if you have the flue gases of a composition which will not oxidize, you can put these castings in such gas but will have no fuel economy. I am assuming that your gases are of the character which will oxidize iron if they come in contact with it. It is barely possible that oxide layers form on the top; as, for instance, while the furnace is still hot but cooling down, sucking air into the fires, you may get oxide layers on the pots, and that will put it on the iron, as iron oxide next time, and the muffle does not do that. I am probably in the dark at this time in an attempt to point out what may be the difference.

As far as temper carbon helping machinability is concerned, I could say a good deal about that. If the temper carbon is where you are doing machining, it is distinctly an advantage, but the automobile man holds you to the closest tolerances. You have let him put you in a place where there

isn't any temper carbon in the particular place where you are doing your machining. An instance of that occurred while Mr. Bean was still at the Eastern Company. We were both interested in this proposition, and he went to a great deal of trouble to furnish very true cylindrical specimens of a particular size on which we cut threads on the efficiency testing machines in our laboratory. These specimens were of a great variety of carbon content and a considerable variety of annealing conditions. I will not expound the thing at length, but the gist of the matter is that the ordinary part of that kind would machine about equally well whether it was a low or high carbon casting in the beginning. We were cutting threads that did not penetrate very far. Had we tested cylindrical bars of that kind by drilling in the center, we would have found the high carbon easier to drill than the low carbon, but on surface milling, the carbon was all gone anyhow. I used to hold the view that temper carbon having once existed, if it burned out left a hole, but in cooperation with the General Electric Co., we found out that that was not true, and consequently you do not even have the benefit of any breakage of a chip by a hole remaining where there used to be carbon.

E. E. Griest: Is there any form of gas analyzer that can be applied to annealing ovens that will be a guide for obtaining the proper air conditions in annealing ovens?

H. A. Schwartz: I think perhaps I am conveying to the meeting the wrong idea, for some who have discussed the paper have looked upon the question as one of actually analyzing gases. So far as I know, without any extended thought or study on the subject, I do not think that is a possibility. I think for any system of control that you work out for the packing question is the answer. You do not determine that your steam engine is running at a hundred and sixty revolutions a minute by reading on the governor and then make an adjustment, but you put a governor on a fly wheel and keep it at the right r. p. m. Now the rather marvelous fact is that Boyden and his successors put on the governor without knowing why the governor worked. Similarly your purpose, as I see it, is not one of controlling furnace atmosphere by making a determination and finding that you have too much CO_2 and correcting by admitting some CO, but to have some such thing as a chemical fly wheel that will keep your gas analysis where you want it. What Mr. Touceda said is exactly true, that we can transmit gases through cast iron at some such temperatures as fast as we want to, but remember that these gases have been in contact with the iron and have obtained a condition of equilibrium with iron, more or less by accident. In my paper there is some information about the decomposition of furnace gases in the pot. The tests were made by purposely orthodox methods of running a quartz tube into the potwall of the furnace. They were made, however, for the purposes of record rather than because we were going to do anything about it if we found out anything about it then and there. We have tested in particular cases where we wished to cut out oxygen by the admission of fuel oil and things like that.

E. Touceda: I did something with this gas which might prove interesting, and Mr. Missimer, for whom I did this work, is present. This particular work has to do with some wedges that were annealed all at one time in the same pot. Perhaps as the work was done by Mr. Missimer, he can tell you more about it than I can. I received the material from him.

W. C. Missimer: From time to time we have seen a peculiar condition arise. We pack all our wedges and tensile bars in the same pots when we anneal them, and we have had wedges from one melting furnace annealed in the same pot with all the wedges from the other three melting furnaces throw an eggshell frame, and the other three sets would not throw any frame. Now what causes the trouble we do not know. The frame is not deep, but it is perceptible; it is there.

E. Touceda: As I understood it, two of those wedges, one being framed and the other not, came from the same furnace.

W. C. Missimer: Yes. We pour five wedges through a heat and we have had three of those wedges from the same air furnace show a frame and two not.

A Member: Were they all poured at the same time?

W. C. Missimer: No, we pour five wedges through the heat; namely, A, B, C, D and E; A is poured at the beginning of the heat and E is poured at the end. It takes about an hour and a half to pour the heat. We only pour once a day.

H. A. Schwartz: What was the ratio of the wedges as between the framed and the not framed?

W. C. Missimer: There was no steady ratio. We might get a frame on wedge C and E and another time on D and B; that is, it was not general or steady, but we have had those freaky cases.

A Member: Was the analysis the same in each case?

W. C. Missimer: The analysis was the same with perhaps a variation of one or two points in the manganese coming down, but not anywhere near great enough to throw your sulphur manganese out of ratio. We laid the trouble entirely to the annealing, and yet we can not see why one melting furnace should throw a slight frame and two others annealed in the same pot should not.

W. R. Bean: In that connection, I have observed frequently when it was the practice to pack tensile bars, that the sides of the tensile bars going towards the rear of the pot would show a frame and appear light, whereas the sides away from the side of the pot would be perfectly normal. There are extremely delicate changes in conditions in the annealing pot, and I have seen many times two wedges, wired together flat, one come out normal and the other abnormal. It was our practice to cast the wedges at the first and last of a heat for a number of years. Very frequently the wedge at the first of the heat would be absolutely normal; the wedge at the end would show a rim or frame, due, I felt, to the progressive increase of sulphur and the progressive decrease of manganese with a lowering of the sulphur. Now there is not much difference, but just enough

difference so that in a metal that was on the borderline between normal and abnormal, there was enough change, enough difference in the composition to account for the difference between a normal result and an abnormal result. It might happen that you would get two conditions. One favoring normal results and one just very slightly favoring the abnormal, giving in one case the unframed condition and in the other the framed. You get the different results because of the delicacy of the process of graphitization in the malleable annealing process.

E. E. Griest: The question of a gas analyzer for the annealing oven is not alone for the control of the castings in the pot, because we do have that. What I am trying to get at is this: If we could get a gas analyzer that would actually indicate the character of the gases that got the best results, we might be able to increase the life of our pots to fifty-five trips, which I understand some foundries have been able to get. I am free to say that we do not come close to that. We have noticed where we have an excessive oxidation of the pots, the physical characteristics of our test bars drop; in other words, with the same analysis iron, the ultimate strength will drop ten or twelve per cent and the elongation may decrease as much as fifty per cent. We have noticed this particularly where we were using an excessive amount of air in our annealing ovens. Of course, you are more likely to get this excessive air with pulverized coal or oil than you are with hand fired ovens. We have tried out various chemical analyzers, but we find that there is some condition prevalent in which the air picks up carbon from the iron and gives a false reading.

Written Discussion

A. Hayes*: This paper is a perfectly obvious application of the equilibria between carbon monoxide and carbon dioxide and the pure iron carbon system. These applications have been rather fully indicated by Dr. Rudolph Schenck, but it should prove helpful to have this application made to the special problem of the oxidation of the surface of castings and to their decarburization.

In the laboratory at Iowa State College, we have carried out a great many annealing experiments in which we packed the white iron specimens in finely ground graphite, and sealed them in pieces of iron pipe. In every case we obtained a marked decarburization at the surface of the castings which would appear to be a slight variation from the results which Mr. Schwartz has predicted. We accounted for this behavior by attributing it to the fact that iron carbide is a metastable phase with a higher escaping tendency for carbon and that the seeding effect of the graphite on the outside of the casting caused migration to take place over appreciable distances near the surface of the casting, with the result that the carbon in this outer portion of the casting was deposited along with the graphite on the exterior. These results were obtained even when the surface of the castings had been ground away before the annealing experiment was carried out.

*Chief Chemist, The American Rolling Mill Co., Middletown, O.

Mr. Schwartz has emphasized rather strongly the influence of dissolved oxygen in some form upon the properties of the austenite and the ferrite, and has neglected to mention the possible influences of the silicon which is present in solid solution, both in the gamma iron and in the alpha iron, in percentages in the neighborhood of one per cent by weight, which is equivalent nearly to 2 atomic per cent.

Considering the very strong deoxidizing influence of silicon, the writer believes that the conditions which exist in the pure system iron-carbon-oxygen will be markedly changed. Since the activity of both the gamma and alpha iron will be lowered by approximately 2 per cent, the exact percentages of the carbon monoxide and carbon dioxide which would represent equilibrium for any set of constituents which included one of these forms of iron would be distinctly changed by the presence of this amount of silicon.

The writer believes that the discussions made in this paper by Mr. Schwartz are qualitatively correct, and the principles which control the condition of the surface of castings during the annealing process have been properly presented.

The writer is also glad to note that Mr. Schwartz has discovered the change which Dr. Schenck found it necessary to make in the relative positions of the carbon and the iron carbide equilibrium curves for mixtures of carbon monoxide and carbon dioxide since the violent attack which he (Mr. Schwartz) made upon the paper by Hayes and Scott.* which was presented before this Association in October, 1925. At this time Mr. Schwartz seemed to be inclined to accept the earlier statements of Dr. Schenck, regardless of the demands of the second law of thermodynamics.

The writer is especially pleased to note this change in Mr. Schwartz's attitude towards Dr. Schenck's earlier work.

The rather wide credence which the malleable iron industry gives to statements made by Mr. Schwartz due to the high position which he occupies in this field makes it extremely important that the impressions which he gives out, especially along the lines of the more fundamentally scientific phases of the subject, be as accurate as possible.

A rather exhaustive discussion of these equilibria is given in bulletin No. 83 from the Engineering Experiment Station of Iowa State College.

AUTHOR'S WRITTEN REPLY TO DISCUSSION

H. A. SCHWARTZ: There remains little to be said in a written closure of this discussion.

Mr. Touceda and Dr. Hayes both point to the spontaneous decarburization of metal at high temperature, presumably because of the vapor pressure of carbon from cementite. This fact was first called to the writer's attention

**The Catalysis of the Graphitization of White Cast Iron by the Use of Carbon Monoxide, Carbon Dioxide Mixtures When Applied Under Pressure.* Trans. American Foundrymen's Association (1925), Vol. XXXIII, pp. 574, 593.

some years ago by Dr. Rosenhain and has since been occasionally observed. The writer knows of no quantitative details and indeed gave it no particular thought in the preparation of the paper, for it is a phenomenon not associated with the subject described by the title. The phenomenon undoubtedly exists and is, of course, of theoretical and perhaps of practical importance in explaining decarburization.

Reference was made by several to vagaries of decarburization on identical metal in rather intimate contact during anneal. Upon reflection the thought has suggested itself that if through difference in character of packing, contact of several castings or otherwise, the free circulation of gas is interfered with, there will be areas in which the reaction products accumulate, displacing atmospheric nitrogen and therefore the partial pressure of the active gas mixture will increase. Differences in this pressure have qualitatively similar effects to differences in temperature, an increase in pressure shifts the equilibrium lines marked Fe_3C and C to the right, but leaves the others unaltered. A shift of this character will have the same effect on the Fe_3C and C equilibria as would a rise of temperature and hence perhaps restricted gas circulation and unequal temperatures may have very similar effects.

Dr. Hayes is entirely correct in the statement that silicon in the metal may distinctly alter the equilibria. The author has referred briefly to the effect of silica in the oxidation products on those equilibria. Nor is there need to confine ourselves to the effects of silicon. Manganese is present and being oxidizable by CO, may greatly alter matters. All the half dozen or so other elements habitually present in small amounts in commercial metal also play their several, though perhaps minor, roles.

It will be noted that the entire paper is cast in a somewhat qualitative form and we discuss what happens in certain fields without defining these by their "metes and bounds," the presentation may perhaps fulfill its intended purpose even without introducing these complexities.

The reader who is not skilled in physical chemistry should benefit by having pointed out to him that departures from the conditions described in the paper may be due to the presence of other unconsidered components.

Dr. Hayes further seeks to revive what he considers to be a controversy on an earlier paper of his own and to lead the discussion into the field of personalities, whither the writer refuses point blank to follow. The subject, however, having been reopened by Dr. Hayes, he and the reader are no doubt entitled to a reply.

The original paper and discussions are to be found in A. F. A. Transactions, Vol XXXIII, page 574 et seq. The facts are that previous to the date of appearance of the Haynes and Scott paper, our principal knowledge of gas equilibria with iron and carbon was due to the work of Dr. Schenck which had been approximately corroborated by Dr. Matsubara, the leading Japanese authority, and was accepted by the eminent Italian, Giolitti, and the well-known British Metallurgist, McCance.

These equilibria were in a direction contrary to the observed facts of graphitization in pure alloys. Nothing conclusive of a direct experimental character as to graphitization in *pure* iron carbon alloys was, or is, known. Such alloys have never been made and investigated.

While it was obvious that either the well substantiated gas equilibria did not apply to the reactions assigned them, or else that our inferences as to the metastable character of pure cementite were incorrect, there is no way to apply the second law of thermodynamics or any other general chemical law to decide between the two horns of the dilemma. Had there been this possibility, it would appear that the authorities cited, who are all of high attainment in physical chemistry, would have made that application.

Hayes and Scott omitted all references to previous work on the subject, giving the reader no warning of the conflicting opinion of other not entirely negligible authorities. The present writer pointed out this neglect, emphasized the fact that he believed the actual observations of Hayes and Scott to be correct and that either the postulated theoretical explanations of these workers might be in error or else that Schenck's inferences from his own extremely numerous and reliable observations were contradicted. Pending a further understanding of the fundamentals, he recommended caution in accepting conclusions contradicting, without explanation, accepted results. He pointed further to the importance of the paper as a possible correction of Schenck and suggested the propriety of Hayes and Scott pointing out any reasons which they might have for believing Schenck's work inaccurate.

A possible means of reconciling Hayes' and Schenck's observations might have been the very effect of silicon on the gas phase equilibria which Hayes has brought out in the discussion of the writer's present paper.

Meanwhile Schenck, investigating independently his own experimental conditions, arrived at the conclusion that the equilibria obtained by him, and also by Matsubara, involved the presence of oxygen in the metallic phase and published the curves now used by the writer and an explanation of the sources of error which vitiated his former conclusions, not his experimental observations. This explanation reached the writer within a few weeks of its German publication and was embodied by him in the present paper, which is the first occasion he has had to speak publicly upon the subject. He further took occasion to point to the fact that the contradiction between Hayes and Schenck had now been resolved in the former's favor.

Inasmuch as he did not anywhere in the discussion of Hayes' and Scott's paper assume to decide whether Hayes' or Schenck's interpretation was correct, but only pointed to the contradiction between them, it is difficult to see how he could have been incorrect at that time, for the contradiction still exists even though the decision has gone in Dr. Hayes' favor as the results of the researches of Dr. Schenck.

Discussion-Need for Research in the Foundry

The paper presented at the Malleable session by E. E. Griest, on the Need for Research in the Foundry, will be found on pages 672 to 682, inclusive.

W. C. Missimer: The splendid thought back of the whole paper is the idea of getting home to the foreman and the supervisers in the shop the realization that they are researchers. So many times there seems to be a breach or chasm between the research department of the plant and general or detailed supervision. A great deal of detail work is left to the research department that could be carried on by the foremen themselves. I notice the author all through his paper refers to the foreman and the superviser in the shop as researchers. When the plant foreman gets the idea that he is part of the research force, that he is just as much a part of it as the men who run the laboratory and those who cope with the larger problems, I think we will make a better product and we will run our plants more economically.

I know that in our plant we have a number of examples as cited by Mr. Griest of research work that we may not have looked at in the light of research work before. Two years ago we had a type of job to make and it looked very much as though that type would increase as to the number of patterns, and we found that the cost of the job exceeded the price at which we could get the work. We had a research meeting, as you might call it. We sat at a round table and we devoted about an hour a day for three days to this particular job. We found that the core cost was an exorbitant part of the whole cost. The job took a core about four feet long. We decided the core cost had to be cut. There did not seem to be any way of cutting this cost, as we made the core in dry sand. After some discussion we found, however, that parts of the core could be made in green sand, which cut the cost in half. We put the green sand core idea into operation on that particular job and found that we were able to make a profit on all the jobs of that type. From the idea of making part of that core in green sand, we were able to elaborate and carry that idea of combining green sand cores with the dry sand core into a great many other jobs.

R. E. Bryant: This paper is of great value to all of us, in enlarging our viewpoint of what might be considered research. We perhaps have thought of research a little bit too narrowly confined to strictly technical matters. It is obvious that the greatest value from the technical work of research comes through the cooperation of the operating force in securing information and in making it useful in addition. The work

of sales research may be of a similar aid in locating new fields for products and new types of products of value.

In our own plant I feel that our purchasing department many times has been a useful adjunct of the research department through bringing to the attention of the technical department new ideas presented to it by salesmen.

An incident which occurs to me and is illustrative of what may be found, is in connection with our machine shop and a cutting solution. We formerly maintained the strength of our cutting solution by frequent additions of the cutting oil and maintained proper emulsion by the addition of soda ash. From time to time the solution would have to be discarded, becoming sour, and the amount of oil used and the amount of soda ash used was a noticeable item of cost. By the development of some simple tests which are now made daily, the exact amount of oil and the exact amount of soda ash are added to maintain the proper mixture. We have found that the amount of those materials used has been reduced about two-thirds and the solution lasts a great deal longer than previously.

Discussion-Cupola Development

R. F. Harrington presided at Session No. 4 on Cupola Developments. The session was convened at 11:00 a. m. on May 15. The first paper presented was on Automatic Blast Gate Control for Cupola Melting by H. V. Crawford. This paper appears on pages 525 to 548, inclusive. The discussion follows:

Discussion—Automatic Blast Gate Control for Cupola Melting

Chairman R. F. Harrington: With the constantly increasing demands upon the foundrymen for high quality of iron, I think that you will recognize in this paper a distinct contribution toward our knowledge on the subject of the elimination of some of the variables.

A. M. Ondreyco: On what do you base your air supply calculation? The diameter of the cupola or the amount of iron you want to melt?

H. V. Crawford: It is based simply on how much carbon you want to burn. Cupola melting is a combustion proposition, and if you want to melt so much carbon, therefore, you need so much oxygen—2.66 lbs. of oxygen per pound of carbon is the theoretical requirement, chemists tell us. Now if you have a lot of holes in the pipe line and your air is leaking out, you have to shoot more air in the line to get the right amount in the cupola.

A. M. Ondreyco: What I don't quite understand is this idea of oxidizing your iron in the cupola with an over supply of CO_2. Supposing in one case we have a cupola operating with 10,000 cubic feet of air. Now what do we do when we blow 15,000 cubic feet of air into this cupola? Do we increase our melt per hour by burning the coke more rapidly?

H. V. Crawford: If you are going to put 15,000 cubic feet of air into a cupola, you have to put more carbon in there in order to combine with it. If you put the same amount of carbon in a cupola when using 15,000 feet of air as when using 10,000, you have an excess of air or an excess of oxygen, and you will get your iron oxidized.

A. M. Ondreyco: Say we have 400 lbs. of coke. We know it requires a certain amount of air to burn that 400 lbs. of coke. With 10,000 cubic feet of air, let's assume that it takes us 15 minutes to burn that; in the case of the 15,000 cubic feet, let's say 10 minutes, for the sake of putting down figures. Then where do we get our excess supply of oxygen there?

H. V. Crawford: You are depending on your melting rate of iron, how much iron you want to melt, in a minute. You base your air supply on the amount of iron you want to melt per hour.

A. M. Ondreyco: I don't see how we are going to get an oversupply of oxygen then. If we want to melt 10 ton an hour we are going to blow

a certain amount of air into that cupola; if we want to melt 15 ton per hour we will use the same proportion of coke to iron; we are going to blow in more air to burn that coke more rapidly. That's what we are going to do, aren't we?

J. T. MACKENZIE: I would like to remark that if you blew 10,000 feet into one cupola and 15,000 feet into another, the melting zones would not be at the same place in the two cupolas.

There was one remark of Mr. Crawford's that I can not agree with, and that was that theoretically you could burn coke in a cupola to carbon dioxide. Now a large part of the disrepute of theory has come from, let me say, just careless statements as that. Theoretically it is impossible to burn coke in a cupola to carbon dioxide. You require 2.66 lbs, of oxygen to burn it to carbon dioxide, but you can never attain that. It seems that we are trying to visualize that the combustion of coke occurs in three steps. It burns from oxygen to carbon dioxide in the first place; then it goes on and burns to carbon monoxide, and there is a further reaction up the stack, where the carbon monoxide can again decompose and deposit carbon on the coke. Now no such thing is possible at all. In fact, we don't know but what some carbon monoxide is formed in the initial stage of the reaction. The blast furnace technologists are still worrying about the question—does the oxygen go directly to carbon dioxide or does it pass through carbon monoxide? There is very grave doubt, for instance, that in a charcoal furnace the carbon dioxide is formed initially.

Going back to the amount of blast. Now the thing that this General Electric device has done for us is that our air doesn't change without our knowing it. If we want to start out blowing 15,000 cubic feet in a 72 inch cupola we can do it; if we want to start with 8,000 cubic feet in a 72 inch cupola we can do it, and in both cases we will get iron with the same coke ratio, exclusive of the bed, of course. The beauty of this thing is, if you want 8,000 cubic feet you simply set a little motor to deliver 8,000 and it will hold it there. You don't have to stay around to see that it stays there.

S. A. MORSE: I have been associated in the development of this device and have had a great deal of experience in the actual use of it on cupolas. The thing that really counts, of course, is the temperature of the iron. One thing that has been demonstrated by its use on the cupola is that the temperature of the iron remains constant. Mr. Crawford could emphasize a little more this fact, that if you set this device to hold a given weight of air you get a constant temperature of the iron.

Now all these automatic instruments and recording instruments and theories mentioned in the paper, perhaps are not of interest in a regular iron foundry. The thing to be emphasized is the fact that you get the constant temperature of iron. If you set the rheostat at a given point, which you have to find by preliminary experimental work, you do get constant temperature of iron. If, having found the best point, you then set the rheostat to get more air than you need the iron would be cooled

off. I think every foundrymen knows that you can have either too much or too little air, but when you have just the right amount of air you will get the best temperature. In all combustion, whether in a boiler or in a cupola, you need a certain exact proportion of air. If you have more air than you need you will have a cooling, and lower the temperature; if you have less air than you need you have incomplete combustion and low temperature.

There is one very startling fact shown by the use of this apparatus and that has been that the pressure has varied a great deal in the past. We have been accustomed to run a cupola by a certain amount of pressure, and when we want 10 ounces of wind or 14 ounces of wind, and if the pressure is a little bit low we think something has gone wrong.

I would like to call attention to one of the charts in Mr. Crawford's paper. On page 543 there is a chart showing the actual pressure on a cupola blower with automatic blast gate control, as compared with pressure on a blower which supplied wind to that cupola, and you see there is a great reduction in pressure and the pressure is variable throughout the run. The automatic blast gate control varies the pressure automatically, and will give the exact amount of pressure and you will get the constant weight.

W. D. Moore: I think Mr. Morse went just a little bit too far in saying this automatic apparatus will guarantee a cure-all against all things. If there is a slip in your coke—if you don't put the right amount of coke in, I don't believe this automatic apparatus will correct that and hold that temperature. I would like to ask if you set it on 600 lbs of air, what is the limitation of the automatic apparatus, how many pounds of air must it vary to trip in and out? Will it trip in at 590 lbs. or will it take 550 lbs. before it will trip?

H. V. Crawford: You can have this device working continuously and hold it in a perfectly straight line, I might say, practically within about 1 per cent or 2 per cent.

W. D. Moore: Supposing we think of an ordinary foundry where the electrician is downtown and the automatic apparatus fails, goes out of order—and don't tell me it won't do that because it will—what are the foundrymen going to do about it? Do you not have a way to set aside this automatic control and go to the hand control when the electric is out?

H. V. Crawford: Yes, we have. The blast gate is simply a standard blast gate. You simply knock out the taper pin connecting the control and the blast gate, and pull the big gear out until it disengages and then you operate it by hand.

Discussion—Cupola Refractories

The next paper presented at Session No. 4 was by C. E. Bales on Cupola Refractories. This paper appears on pages 683 to 696.

F. E. Reiners: Is there any advantage in the double lining? By that I mean the lining of common brick faced with a 4-inch block, we

will say, on a 6-inch block, over the old type of single lining of 9-inch block.

C. E. BALES: I believe there is a decided advantage in using the 6-inch block. The principal reason is that it does not cost as much as the 9-inch block and if you line with a 9-inch block it doesn't take long for that block to wear down to about 6 inches. This is due to the relatively poor heat conductivity of fire clay blocks. The heat cannot escape as fast through a 9-inch block as it can through the 6-inch block and so much heat will be stored up in the larger block, that a certain amount will burn off on the hot face. It has been my observation that the hot end of the block will burn off rapidly until it gets down to about 6 inches.

J. T. MACKENZIE: I am rather inclined to take issue with Mr. Bales on that point. When you put in 9-inch block, especially in the abrasion zone, you have a good job as long as any brick is there at all. If it wears down to 2 inches, you still have a lining, but if you put in 6-inch block it will fall out when it is worn to about 3 and you have to put in a whole new 6-inch block. I think it is false economy to put in a double lining.

C. E. BALES: Mr. MacKenzie is right on that point as to the abrasion zone. I was thinking principally of the melting zone. In the abrasion zone heat conductivity is of no importance.

Discussion–Cast Iron Developments

J. W. Bolton presided at Session No. 7, on Cast Iron. The session was held at 10:00 a. m. on Wednesday, May 16. The first paper presented was that on Some Recent Developments in Cupola Metal by J. D. Miller. This paper will be found on pages 697 to 703, inclusive. The discussion follows:

Recent Developments in Cupola Metal

J. T. MacKenzie: I would like to comment on the use of the words "better iron." Now 65,000 tensile strength is fine for those castings where you want that strength but there are lots of castings made where fluidity is the paramount consideration. I think we should say "strong iron" in this connection and not make the general statement that we are making a better product.

D. McLain: We began some time ago, and finally succeeded in making a better metal. This was about 25 or 28 years ago, but we did not get 45,000 tensile strength because there was no demand for it. I will say that within twenty years we have not been asked to make a metal of that tensile strength. I don't see any need for 60,000 to 70,000 tensile strength, because if any one wants a metal of that strength he wants steel.

H. Bornstein: We have done some work along experimental lines in producing high test iron, but we have only made about half a dozen heats of this iron. We use all steel—the charge being about 96 per cent of steel rails and the necessary manganese and ferro-silicon. We arrange to add enough manganese so that the metal coming from the spout has a manganese content of about 0.65 and silicon about 1.00 to 1.25, then we add the balance of the silicon to raise the silicon content to 2.25 and sufficient nickel shot to obtain a nickel content of about three quarters of one per cent, and about one and one quarter additions are made to the spout. We melt with a very high, close bed, the bed being about 48 inches. By doing so we obtain a very hot metal right from the start. The temperature measurements are taken with an optical pyrometer and run between 2700 and 2800 degrees Fahr. We have made a number of castings from this particular metal. The tensile strength of the iron on our tests has averaged about 65,000 pounds and our highest was about 70,000. I think the highest test of a bar gave 69,800 pounds tensile strength.

We have not had much trouble with the fluidity of the iron to fill the molds, and the castings as a whole have been very satisfactory. I

don't know how this method would do for large sections in castings. We have run half a dozen heats and each time we have made about 50,000 tons of castings.

A. E. HARRISON: Any movement that tends to betterment of the product is one to be looked upon with favor by all of us. I think Mr. MacKenzie brought up the important point in the whole matter and that is that we are not after better iron so much as better castings and there is a big difference between the two. This was brought out in one of the papers that was read. The writer recognized in his work the necessity of performing effectively certain work in the foundry that would permit of a sound casting, because no matter how good your iron may be, if it is not properly handled in the foundry in production of the mold and the casting, we have only obtained better iron and not a better casting, and we are after better castings.

J. D. MILLER: Electric and air furnace metals have been much discussed as to better metals; that is, metals of finer grain and higher tensile than made in the cupola. My paper was to deal with this higher quality metal made in the cupola. As to making better castings, that is not limited to better metal at all. To get better castings, we must have the best materials (which embraces many things besides the metal), the best practice and better and more economical conditions, etc.

J. W. BOLTON: A great many of us have been interested in a better iron for a number of years, and better methods and means of production, but I want to say I believe many have gone too far in their efforts to improve materials.

As a matter of fact, cast iron has decided limitations. It is also true that there is not enough known about the engineering properties of cast iron. Our knowledge is from results based on the test bar which in many cases bears no relation to the properties of the casting proper. The rigidity of cast iron is so great that naturally its use is measured largely by that property and the elasticity.

J. D. MILLER: As to the machinability of the work castings we are producing, I can cite an example. We are making a press plunger that must be very close grained and take a high polish to withstand severe wear. It is about 13 feet long, and 12 inches in diameter, with a wall thickness of one inch finished. We cast this plunger from metal of 65,000 pounds tensile, metal which was very fine grain and gave a beautiful finished surface but which was so hard that it slowed up the machining. We then dropped our tensile down to 45,000 pounds and found that the grain refinement answered the purpose with machinability normal. We have experienced no trouble machining castings of 50,000 to 60,000 pounds tensile strength at regular machine speeds. I am speaking now of medium and heavy sections. With lighter sections, we have had little experience.

Temperature Measurements of Molten Cast Iron

The third paper presented at Session No. 7 was on Temperature Measurements of Molten Cast Iron by H. T. Wensel and W. F. Roeser. This paper appears on pages 191 to 212, inclusive. The discussion is given below.

Chairman J. W. Bolton: The use of the optical pyrometer in heat treatment is interesting to many of you. It has been demonstrated that this instrument is practical, especially where you want to get away from pitting. However, there are discrepancies in the reading of the instrument and many people doubt whether it is practicable. This work that the Bureau of Standards has done does prove its value.

N. C. Moore: Does the light in the foundry at the time that the optical pyrometer is used have any effect on the reading?

H. T. Wensel: I would not worry about the light in the room unless it is bright sunlight which is reflected directly into the pyrometer. The reflected light is usually only a small fraction of the total light reaching the pyrometer. Even if the light reflected from the room into the pyrometer was 1/10 of the light radiated by the metal, it would mean only an error of between ten and fifteen degrees Centigrade at 1400°C.

N. C. Moore: We have the iron very hot in the cupola and it is put in the ladle and cools down and scales start to form as patches in the middle. These spread as the cooling continues and it gradually covers the whole surface of the ladle. Now, would you recommend allowing the scale to continue to form as you watch the cooling or would you keep the surface of the metal clean?

H. T. Wensel: These patches that you mention, are they brighter than the rest of the surface?

N. C. Moore: Well, I would not say brighter, but of a different color. It has a different appearance.

H. T. Wensel: Those patches forming are an oxide film and form slowly or suddenly according to the iron. In a nickel or chrome iron it forms very suddenly. If the pyrometer is sighted on the bright patches the smaller corrections, around 40°C, should be applied. If the darker portions are observed or if the iron is kept freshly skimmed, the higher corrections, around 100°C, should be applied. Either method, if proper correction be selected, will give the same value of the true temperature.

J. T. MacKenzie: When that film gets thick it cools on the top. You will note in Table 3 that the general rule is that the correction goes up slightly as they get down to the cooler iron, and that is due to the fact that the top cools sooner than the iron beneath.

R. F. Harrington: When this general question was brought up, the question of the effect of the addition of alloys in the ladle was also mentioned, ferro-silicon and nickel, but apparently that was not considered, as I do not see anything in the paper as to where the additions were made. I wonder if the investigators believe the conditions would have

been affected if the alloy additions had been made at the spout instead of in the furnace.

H. T. WENSEL: I think Mr. Saeger can better answer that question. He prepared the irons for our use and he may recollect better where the nickel and chromium additions were made.

C. M. SAEGER: There were several grades of irons used in this investigation, as shown on page 201. In Table 5, you may note the percentage of alloy additions.

W. F. ROESER: In Table 4 the nickel varies from one-half up to three per cent, and the chrome one-half to one per cent. The transition point on steel is at a higher temperature than on iron; about 1500°C on steel while on iron it is amout 1375°C. Another thing you must consider is the appearance of the iron; above the transition point the surface has a greenish tinge, while below this point it has a reddish or yellowish tinge and the character of the surface can be recognized by its color. The large corrections are applicable when the surface is greenish.

R. F. HARRINGTON: The additions you speak of were made in the furnace or in the ladle?

C. M. SAEGER: Most alloy additions were made in the furnace, while others were made in the ladle.

R. F. HARRINGTON: Does the condition differ according to where the addition is made?

H. T. WENSEL: We did not understand that it was of any interest to determine this point. However, as it happens, we made additions in both places and noticed no difference in the behavior of the iron. I think we can say it makes no great difference, although we were not specifically looking for such a difference and may have missed one unless it was large.

Discussion–Cast Iron Metallurgical Developments

H. W. Gillett presided at Session No. 14 which convened at 10:00 a. m., May 17. At this session two papers were presented. The first by John Shaw on Theory or Practice in the Gray Iron Foundry, will be found on pages 293 to 322. The paper by J. W. Bolton on Research Problems of the Gray Iron Foundry appears on pages 469 to 512, inclusive. The discussion of these two papers follows:

Discussion—Theory or Practice in the Gray Iron Foundry

Chairman H. W. Gillett: This session is primarily concerned with research methods and plans, as I see it; that is the thread which runs through the papers. Research is only research where we do not know what we are going to find out, when we are running into unexplored and uncharted fields.

It seems to me that this whole situation might well be considered as analogous to that of navigation. If you have ever seen any of the old time maps of away back in the fifteen, sixteen, and seventeen hundreds, you will notice that the ancient cartographers had a general hunch as to where there was a continent or island or something of that sort, and they put it down about where they thought it was. But they had a lot of blank spaces that they could not fill up so they used to put in mermaids and things of that sort. You will find some of those old maps very interesting.

The amount of information that Columbus, for example, had to guide him on his voyage was zero. He was going out to an entirely unknown destination. He himself did not know exactly where he did get, but he got somewhere. At the present day the mariner has a chart which gives him all the information he needs. He can take either an ocean liner or a shallow draft vessel into any harbor in the world, whether he has been there before or not, because he has the information down in a usable form on a chart that he can read and it will guide him.

Now similarly that is what we need in the metallurgical industry; especially in the gray iron industry. We need charts which will allow us to tell what we are going to get in a casting when we have not made that casting before. We should know the engineering properties of our materials well enough so that when we have a given purpose to accomplish, it can be accomplished by the selection of composition, casting temperature, and anything else along the line.

When you are in a fairly simple field, it is not such a job to make up a chart. For navigation on the sea, the methods are fairly well outlined. When you come to air navigation you introduce more variables.

First of all, you are working in a third dimension, and then you have your air currents and all your meteorological disturbances, which are entirely unknown. It is perfectly safe to say that in the course of time all those factors will become known and can be predicted, and air navigation of the future, and probably not such a far distant future, will be in nearly as good shape as navigation of the seas is today.

In this cast iron proposition, we are getting into a very complex field, with many elements entering into the materials and many complex factors entering all through the processing. We cannot lay out our charts without instruments for getting our soundings and all that sort of thing, and the tests that we perform upon the castings either in the shop or the laboratory are the instruments. We are in a comparable condition to the early navigators, with a compass and not much of anything else. The trans-Atlantic fliers at the present time have a ship full of gasoline and instruments, and if there is any room left, they will put in a navigator or two, but you will find that the instruments are the important part of the outfit. The methods of charting the information we need, getting it down into coordinated and useful form, are very important studies, and it is perfectly proper that a session of the Association be devoted to a broad gauge, long range view of the question of how we are going to coordinate and chart the information that we have and fill the gaps so that ultimately we will have a chart which will serve the foundrymen as the navigator is now served by his chart.

I have been talking about navigation and trans-Atlantic flying, and so on. This international flavor is very notable in this session, because of the eminent man whom we have here today to speak to us. He does not need any introduction. He is an iron foundryman, but I would also class him as an eminent non-ferrous metallurgist, because he shows a great ability to collect gold medals. Mr. John Shaw will speak to us on the subject of Theory or Practice in the Gray Iron Foundry.

Mr. Shaw then presented his paper in abstract. The paper is reproduced on pages 293 to 322 inclusive.

J. W. BOLTON: Mr. Shaw's paper of course is a paper of great intrinsic worth. Besides that, it is a paper that makes one think. The paper is permeated with questions. He brings up things usually accepted without question and turns the searchlight upon them. If there were no other good done by the paper—and there is much other good done by it—that one attitude justifies the paper receiving very high praise as a stimulant to thought. I have submitted a written discussion; this oral discussion is largely an apology. In a certain part of Mr. Shaw's paper, he refers to cooling rates on different sizes of test bars. In that he has referred to a paper which we presented to the Belgian Foundrymen's Association a couple of years ago, giving the cooling rates of a casting with the corresponding heating rates of a sand mold, the mold in which the casting was made. On that chart which you see in the paper there, the analysis of

iron is given under physical tests on the old A. S. T. M. bars, and nothing is said about the size of the bar from which the cooling rate was taken. Unfortunately for me, Mr. Shaw interpreted the cooling rate as applying to the old A. S. T. M. bar. It does not. It applied to a four inch bar.

Do you remember where Mr. Shaw took the ratio, silicon plus carbon, and showed that by taking that ratio, silicon plus carbon, with low carbon and high silicon, we had in one case a high sum connected with a high strength, which from previously published works, both in this country and abroad, one would become very dubious about? He has the figures on it, and goes on and shows again a low sum, a thing that, at first glance, would seem contrary to the experience of others. However, if you will take these same figures and weight the silicon properly by taking either the figure Mr. MacKenzie has used, which is carbon plus one-fourth of the silicon, or the figure which is used in the paper we have this morning, carbon plus three-tenths of silicon, Mr. Shaw's results are reversed and the strength figures fall in proper order with the relationship between silicon and carbon.

Mr. Shaw was so very kind as to give me a paper written by one of the eminent British metallurgists in which quite violent exception was taken to our contention as to the form of phosphorus in cast iron. This gentleman had the idea (I do not know just where he got it, certainly not from any of my original complete writings) that we claimed that there was rarely less than five-tenths of one per cent phosphorus where there were any cellular eutectics present. That is not true. The cellular eutectic formation is found in low phosphorus iron, but in much less amount.

J. T. MacKenzie: Every man in the room and all his friends should read part 2 of Mr. Shaw's paper. In many ways that is the most valuable thought contained in the paper. It seems as if every one is ready to give cast iron a black eye and the apparent facility with which they are able to ignore defects in steel, which also might be termed unreliable, is astounding. If you listened to these engineers talk you would think that the only material in the world that is unreliable is cast iron. I would like to ask Mr. Shaw a question. In Mr. Donaldson's work on the heat resistance of cast iron, how high a temperature does he find that the phosphorus permits the strength to remain up to the useful limit?

J. Shaw: Mr. Bolton's explanation of his sand heating and bar cooling curves cuts both ways. While the cooling curve of the bar due to the larger diameter cuts out the comparison with Hamasumi, its very size should heat the sand up quicker and make the comparison between Bolton's and Maurer's curves greater still.

I agree with Mr. MacKenzie as to the very vital issues raised in part II of the paper. I can find no evidence that good cast iron is more liable to failure than steel. Its wholesale condemnation in some quarters is due to lack of some definite standards against which to measure its

qualities. This is not so on steel. I am afraid the foundrymen's knowledge on this question is not much better. Hence the vital need of such papers as we are having this morning.

Donaldson's work was carried out at 500 degrees Cent.

There are three errors in the paper which I would like you to correct.

On page 305 the bottom paragraph; the quotation was from Baurmann and not Crome.

On page 314, next to last paragraph, the B. E. S. A. test bars were 1.2 inches in diameter instead of ½ inch.

On page 309, next to last paragraph, the figure 1944 should read 243.

The article by Homma was Studies on Chill Castings, published in Kenkyu, Vol 3, No. 2, 1926; the article by Crome was Sulphur in Malleable and appeared in the Foundry Trade Journal of September 8, 1921. The articles by Hamasumi appeared in the Foundry Trade Journal for March 19 and July 25, 1925; that by Coe was a paper presented before the Iron and Steel Institute, Vol. 2 (1910), p. 105, and the article by Hagen and Turner appeared in this same Iron and Steel Institute Journal on p. 72.

Written Discussion—Submitted by F. J. Cook*

John Shaw's paper points out on the one hand the lack of appreciation of engineers generally as to the value of cast iron and of the efforts being made by founders to improve the quality of it, and on the other hand it suggests the herculean task of correlating the effects of the host of variables with which the founder has to grapple.

The seemingly little progress made in elucidating the latter is not to be wondered at when it is remembered that almost incalculable combinations that may arise with the variations of the amounts of the several chemical elements that occur in ordinary commercial pig iron, to which has to be added variations in temperature and working of the blast furnaces, variables in cupola working, rate of cooling, mold conditions, etc., etc.

However, the writer is quite of the opinion that success largely lies in striving for and arriving at a proper ratio of the various chemical elements one to the other, to suit the various classes of work and conditions of working.

It can be safely stated that the total carbon present and the condition of this element is the predominant factor in determining the physical properties of the metal, and the values of the other elements are in direct ratio to the effect they have upon the carbon.

Silicon is probably the easiest element to apply for regulating the condition of the carbon and a proper ratio of the two elements, silicon and carbon, goes a long way in arriving at a satisfactory starting basis for analysis.

The formulæ, for the ratio of silicon and carbon, given in the

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writer's exchange paper* to the A. F. A. in 1922 has been found to stand the test of time when considering results obtained not only with every-day work, but also when considering some freak results which have been met with from time to time.

To deal categorically with all the elements is not permissible, within the scope of a discussion, but the following points in connection with phosphorus, which are in accordance with the writer's experience, may not be considered out of place.

When the ratio of silicon and total carbon as called for in the aforementioned formulæ is that ascribed to give the highest tensile strength, no detriment in strength has been found with phosphorus of one per cent with recorded daily results over very many years.

The following table gives results obtained recently by an independent, disinterested person who selected bars at random:

Tensile Strength lbs. per sq. in.	Transverse lbs.	Modulus of Rupture lbs.	Impact Test 48 ft. lb. blows
36,960	4,536	81,648	531
38,080	3,304	59,472	506
42,784	4,088	73,584	306
44,128	3,664	65,968	614
44,912	4,190	75,350	627
47,264	.....	73,920	656

Each bar represents a different day's cast. The tensile bar was cast 1¼ inches diameter turned to ½ square inch area. The transverse bar was cast 1¼ inches square machined down to 1 inch square and tested on 12 inch centers. The lowest phosphorus in any of the bars was 0.7 per cent. Dilatometer results obtained on the last bar in the series when heated up to 1832° F. is:

Bar broke down at 1792° F.

Pearlitic change Heating 1468° F.

Pearlitic change Cooling 1369° F.

which shows excellent results notwithstanding the high phosphorus content.

Metal of this class with phosphorus of one per cent is working in a large number of superheat steam engines where the total temperature of the steam is 572 degrees Fahr. and over without giving any trouble. In fact, the reason that prevents high temperatures being dealt with is carbonization of the cylinder lubrication.

To prove that under the formulæ condition as to silicon and carbon, no bad effects would arise from even excessively high phosphorus, pistons, to replace some that had given bad results in foreign made Deisel engine, were cast with a low manganese content and phosphorus of 1.4 per cent and the castings gave quite successful results.

Phosphorus increases the resistance to wear as pointed out by Mr. Shaw. It also reduces the total carbon and the amount of the carbon in the matrix, giving higher percentage of ferrite. Phosphorus refines the pearlite tending to make it granular instead of striated. When the phos-

**American versus British Gray Cast Iron,* Trans. A. F. A., Vol. 30, p. 124.

phorus is wholly in the cellular form, by surrounding the grains of pearlite it protects them from oxidation and thus tends to reduce growth.

It has, however, been the experience of the writer that there is a phase corresponding to 0.5 per cent phosphorus which tends to trouble from segregation and porosity and this has recently been confirmed by two of the largest motor cylinder makers in this country and also by the results of some tests in connection with a research now in hand.

It is, therefore, suggested that phosphorus should be 0.4 per cent or under or 0.6 per cent to 1 per cent for high duty irons.

The whole of the above remarks are based on a proper ratio of the silicon and carbon, but where this does not exist phosphorus may be distinctly harmful.

The discussions of Mr. Shaw's paper which follow, were first printed in the *Foundry Trade Journal,* and are reprinted here by permission.

J. G. Pearce:[1] The questions raised by Mr. Shaw in his paper are of great importance and of particular interest to the British Cast Iron Research Association. He asks, in effect, whether it is not better to study cast iron by what might be described as the analytic method—that is, by starting with a base that is undoubtedly cast iron, and making suitable variations on that—rather than by what might be described as a synthetic method of taking a pure iron-carbon base and building up by adding appropriate elements. It is quite true that in the latter case the ultimate material does not behave as ordinary cast iron behaves, so that the results are distrusted accordingly. An effective study of the subject by the latter method would also occupy an army of research workers for several years, and the cost would be greater than the industry in its present state can bear. The study would be complicated by effects, some of which Mr. Shaw has mentioned, such as the influence of gases, pouring temperature, etc. The application of the results would be open to doubt, due to the fact that in cast iron practice the metal never reaches a state of equilibrium. On the whole, therefore, we sympathise with Mr. Shaw's suggestion that the material worked on should be a cast iron, and for some time past the Association has carried out experiments on a base which, while not of the same analysis as that given by Mr. Shaw, has been made in the open-hearth furnace, and is low in total carbon, silicon, manganese, phosphorus and sulphur. Even this method, however, presents its difficulties. It would not seriously be possible to study the influence of manganese and sulphur on a base containing manganese 0.5 and sulphur 0.03 per cent. In order to deal with this question it is necessary to start with a manganese-free, sulphur-free base, and to ascertain the effects of each before they are tried in combination. It is thought that the Cast Iron Research Association can do its most effective work on cast iron by utilising a cast iron base of the kind suggested, melted in furnaces of the kind used in the trade, the crucible and the cupola. We

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[1] Director of the British Cast Iron Research Association.

see no reason why national and university laboratories should not study along the synthetic lines, as work such as that of Dr. Hanson, while, as he himself admits, not directly applicable to grey iron practice, is immensely valuable in suggesting new ways of looking at cast iron and its behaviour, and these in turn influence the more practical work. An interesting illustration has recently been afforded of the value of the two methods by our recently work on nickel in cast iron, which was first studied in the University of Birmingham on a laboratory scale by making synthetic mixtures, and as information was obtained this was followed by practical full-scale melts in crucible and cupola furnace, with very useful results.

Too much importance should, perhaps, not be attached to isolated figures of total carbon and silicon quoted by various investigators from bars of similar size. In many cases there were special features about the work which would explain some of the differences found; the rest of which could probably be explained by reference to pouring temperature moulding conditions, etc. As Mr. Shaw is aware, the variations he quotes from experimental records are not found in ordinary practice.

It would be regrettable if the view expressed by Mr. Shaw regarding German advances led anybody to think that they were not dependent on metallurgical knowledge and training. While they are extremely practical, and arose out of practical experience, they come from men who have profited by the intense metallurgical training available in Germany.

Another point of great importance which is being met constantly in practice is found in experimental work; that is the heterogeneity of mixtures which are often presumed to be homogeneous. Rich and lean ferro alloys added to a given base to produce the same amount of added element do not give the same results.

The foundry industry is under a very great debt of gratitude to Mr. Shaw for his pertinacity in pursuing the results of investigations and pointing out the discrepancies between them. In this way he succeeds in focussing the attention of metallurgists upon the spots where attention is most needed, and it is highly probable that some of the more pressing problems he mentions will have light thrown on them in the near future.

F. J. Cook:[3] I have studied the effects of this element on high duty irons very closely for at least 25 years, and my experience is that where the silicon and total carbon exist in the ratio given in my formula for high tensile irons, a phosphorus content up to and including 1 per cent has no detrimental effect upon *any of the physical properties* of the metal. In physical properties I include tensile, modulus of rupture, impact, dilatometric phenomenon, etc., but where the condition as to ratio of Si and total C do not exist then phosphorus has a very marked effect. I have never failed to search for any evidence of bad effects in my conditions, but have never met a single case.

On the other hand, however, wherever you find quoted bad examples

[3] M. I. Mech. E., past president of the Institute of British Foundrymen.

of the influence of phosphorus you will invariably find the ratio of C and Si to blame.

In my ratio of C and Si I have always aimed at 3 per cent total carbon and a corresponding 1.2 per cent of Si.

In my experiments with cylinder iron I, a long time ago, found that 0.5 per cent phosphorus showed a decided tendency to segregation, porosity, and a tendency to cracking, but when this element was raised to 0.7 to 1 per cent these bad effects were eliminated. That 0.5 per cent is a deleterious quantity has since been confirmed by the metallurgists of two of the best motor cylinder manufacturers of this country, who each independently of the other have experienced the same troubles. With this in mind, in connection with a research now going on, I suggested that with cupola-melted irons the range of phosphorus—which goes from very low to very high—should contain one of 0.5 per cent, and the results obtained showed that this one gave results *much out of step* to those obtained with other quantities present, although with refined irons the results were not so pronounced.

I therefore always suggest that this 0.5 per cent range should be avoided, recommending either 0.4 per cent and below or 0.6 per cent and up to 1 per cent, leaving each one to make his choice.

That phosphorus reduces the total carbon has been shown by many workers, particularly Stead: but attention has not, as far as I am aware, been called to the fact that phosphorus by virtue of its taking up carbon leaves more ferrite in the matrix.

Take my cylinder metal, *i. e.*, total carbon, 3 per cent; C.C., 0.8 per cent; G.C., 2.2 per cent; Si, 1.2 per cent; Mn, 0.4 per cent; S, 0.12 per cent; and take out the constitutional analysis with 0.4 and 1 per cent phosphorus, and you get the following result:

	Phos. 1 per cent	0.4 per cent
Graphite	2.2 per cent	2.2 per cent
MnS	0.33 per cent	0.33 per cent
Phosphide eutectic ternary	14.5 per cent	5.8 per cent
Pearlite	55.0 per cent	73.5 per cent
Ferrite	27.97 per cent	18.17 per cent

Thus the hard phosphide in the network formation holds up against wear, whilst the extra ferrite butters down and take up quickly the high polish necessary to all good wearing conditions.

Phosphorus, like nickel, I find refines the graphite, also refines the pearlite, tending also to make it granular instead of striated.

That phosphorus is not detrimental to high physical results I showed in my American Paper; since then the following results have been obtained by an entirely unbiased gentleman, who selected haphazard a few test bars which were in stock, and which he found gave the following results. The bars were cast 1¼ in. diameter and turned down to ½ sq. in. area for tensile test.

Tensile test—Tons per sq. in......	16.5	17.0	19.2	19.7	20.1	21.2*
Transverse test—1 in. sq., 12 in. centres	40.5	29.5	36.5	32.75	37.5	——
Modulus of rupture—Tons........	36.45	26.55	32.85	29.45	33.75	33
Impact—.48 ft.-lbs.	531	506	306	614	627	656

It has been considered by Fletcher that dendritic structure would always give poor physical results. It is interesting that the structure of the last bar quoted in the table above was as dendritic as possible, yet the results are exceptionally high in every test, and shows that a dendritic structure in this case has not been harmful.

W. B. Parker:[3] The opening remarks mainly give me the impression that you are somewhat adverse to what Mr. Shaw has termed the "Synthetic" method of ascertaining the action of an element—such as silicon or manganese—upon the structural constitution, also the mechanical, chemical and physical properties or practical behavior of any cast iron.

But unfortunately for your readers, Mr. Shaw does not define the scale upon which the synthetic experiments to attain this object are performed and this leaves one in doubt as to whether he would or would not accept as "practically satisfactory," in a foundry sense, the results of synthetic methods conducted upon, say, 1-cwt. or 4-cwt. lots, or even still larger quantities, per melt.

If these so-called synthetic methods are attempted upon *small* weights of material—say, anything under 1-cwt. lots of each mixture—I am very much in agreement with you, since there is undoubtedly a point in the "quantity" scale of the melting work where certain of the always occurring variables have an exaggerated influence, *i. e.*, their effect upon certain properties are exaggerated in comparison with their effect when larger masses are prepared, *i. e.*, melted all at the same time.

For this reason I am always sceptical of the working value or practical foundry value of work done at the national institutions both at home and abroad which employ less than 1-cwt. melts of each mixture prepared.

For instance, the recent interesting paper by Everest, Turner and Hanson, which is based upon 24-lb. melts of each mixture, is, to my mind, unsatisfactory if the results are claimed to represent in any quantitative or positive manner "cast iron," *i. e.*, as the actual foundry trade understands the matter. It is, however, necessary to notice in this particular paper that the authors definitely disclaim such a direct application. It is just possible that this repudiation of this claim is due to the fact that the chief author, Dr. Everest, was for several years under me as an apprentice and he learnt by contact with our foundry the effect of quantity.

The above critical attitude, of course, holds, still more severely when one contemplates some of the N.P.L. work which has been done on quantities of 4 to 8 ounces.

*The last example was sent later and was not one of the bars he had taken away. Each bar is from a different day's cast.

[3] Chief chemist to the British Thomson-Houston Company, Ltd.

Much of the Japanese and Continental work is of this very small scale type, and I think Mr. Shaw is doing a good service by calling attention to the doubtful value of such work to the grey-iron foundry.

On the other hand, if the synthetic method of investigation is conducted by using melts of 1 cwt. (112 lbs.) or more at a time (and I know privately many such investigations), I am willing to accept the results as being on a sufficiently large scale to give very fair practical results upon which a foundry manager could base his still larger everyday production without fear of loss or irregular results.

Melts of 1 cwt. permit of making several large sample bars from 1⅛ in. dia. upwards, and moulding them in a strictly similar manner to those employed in a large portion of ordinary foundry work, *i. e.,* with ample "heads" and other practical features.

To such a bar the objection with regard to the ratio of superficial area to cubic content is not applicable, for instance, the 1⅝ in. dia. bar of 15 in. length will weigh approximately 8 lbs.

It will have a cubic content of 31 cub. ins., and the superficial area, including ends, will have the ratio to content of 80.6 to 31.0, and the circumference is in the ratio of 5.1 to 2.07 sq. ins. cross-sectional area. This type of ratio holds good for a considerable quantity of grey iron foundry work.

With reference to the use of synthetic methods in steels it will be found that a very considerable portion of the snythetic investigational work upon plain carbon steel, alloyed steel and steel alloys which has been conducted in France, Germany, and Great Britain has been performed on individual melts of the order of 1 cwt., and, so far as the results obtained have been applied, the information so got has been sufficiently practical to enable the steelmakers to go straight ahead and make up, say, 2- to 5-ton lots of the material *and obtain first class practical results* and follow up immediately with 50-ton melts.

Influence of Mass

This fact, I think, fully vindicates the use of the synthetic method for metallurgical investigation—but, as I say, its practical value is entirely dependent upon employing a sufficient quantity of melt to swamp those effects which tend to have exaggerated influence when small quantities are melted, and yet, on the other hand, allow those laws which are of paramount importance and influence in ordinary foundry work to get into action and exert their influence upon the test results.

Further, even if such an investigation has in the first instance been conducted upon a series of alloyed steels—for example, say, "Mn + Si" steels, the results obtained *can be applied directly and successfully to cast iron,* provided ordinary commonsense metallurgical forethought and foresight are employed in the process of application. *There is no doubt about this,* because I have tried it and proved it personally.

It is worth noting that a considerable amount of this synthetic research work on steels concerns material containing over 1 per cent carbon and

silicons over 1 per cent. Such results are getting near to our low total-carbon cast irons.

Here, then, is opened up a wider source of existing synthetic information, primarily obtained for steel making, but which is extremely useful to grey cast-iron foundrymen, provided they have had a real metallurgical training and have at hand the help of a good laboratory.

It is in this sense that I am a strong advocate for the large-scale synthetic method of investigation in cast iron, and the application of the indications obtained in steel to the planning of such work in cast iron.

Manganese Hardens Cast Iron

I do not quite agree with Mr. Shaw's attitude upon the question of the action of manganese on grey cast iron. If one starts with a grey pig-iron containing 0.8 per cent silicon, but which contains not over 0.05 per cent of sulphur and not over 0.25 per cent manganese (there are such pig-irons produced by the ton per blast furnaces), and then keeping the silicon, total carbon, phosphorus and sulphur steady, one increases the manganese alone to quantities such as the following: 0.5 per cent up to 3 per cent in 0.25 per cent increments, and after this 3.5, 4, 5 and 7 per cent, the results of electrical and mechanical tests (tension, compression, shear, transverse and hardness), also chemical and microscopic tests upon such a series of melts will show:—(1) A steady increase in strength; (2) a steadily increasing stability of the carbide (in the case of mixtures low in silicon, the carbide is the double carbide of iron and manganese), thus proving the manganese increases the solubility of the carbon in iron; and (3) a fairly steady increase in the combined carbon percentage which is equivalent to a general increase of hardness of the metal. Hence manganese *does* harden grey cast iron.

Procedure for Research

Of course, to get a full knowledge of the combined action of manganese and silicon it is necessary to make several such series of alloys. Personally, I would say at least 14 series with varying silicon contents, but in each series the silicon to be constant at one or other of the specified percentages below. If I were scheming such a series of tests I should employ the following percentages of silicon:—0.5, 1.0, 1.25 per cent, and continue the 0.25 per cent increments up to 4 per cent. This means 210 melts, each of at least 1 cwt. quantity. To make 210 melts is obviously a big task. The amount of practical work is very considerable and the cost rather high. Also it demands a first-class leading metallurgist and a thoroughly well-organised and sufficient staff of investigators. If only two melts per day could be made or, say, 10 to 12 per week it would take about 20 weeks' constant melting to get all the samples. Then as regards their testing it would be fairly certain that only one or two melts could be completely tested, and a proper consideration given to the results *per week.*

Suppose that two melts were dealt with completely and the records all

written up, this means at least two years' constant work for a fairly large staff group, say, four experimenters and a senior assistant. In spite of the magnitude of the task thus outlined I consider it is urgently needed, and would repay itself, and that the results would be of permanent and practical value to the industry.

With further reference to manganese, the unsatisfactory points about the quoted Japanese work are that only five points are given and the silicon varies 0.25 per cent in the series, also they do not start low enough down the silicon scale (it ought to have started with one-half the amount Hamasumi used).

It also ought to have included much higher silicons and the manganese ought to have gone up in much smaller and regular steps, for instance there is a step from 0.69 to 1.34 per cent Mn. But in spite of very self-evident deficiencies and doubtfulness of the results the results emphasise the fact that manganese does:—(1) Retain the carbon in combined form, and (2) harden grey cast iron in two of the usual test methods of determination of "hardening" (even in the presence of 1.7 per cent silicon).

It is therefore erroneous when the Japanese state that in grey cast iron, manganese up to 2 per cent (in the presence of silicon) does not retain carbon in the combined form. Their own test values disprove this, although they are too scarce in numbers to be very convincing.

How Manganese Acts

Personal experience and early experimental work have shown that: (1) When there is no sulphur present, the first 0.1 per cent manganese acts in the same sense as in steel, namely, as a deoxidiser; (2) if there is over a trace of sulphur (for argument, say over 0.02 per cent S) the first one or two-tenths per cent of manganese react with this sulphur and form MnS, the excess of Mn (if any) above this requirement then acts firstly as a deoxidiser, and then the *final* excess has its own true action upon the bath of molten cast iron; (3) this "final" excess undoubtedly has a hardening effect on grey cast iron in that it retains and increases the percentage of combined carbon; and (4) the hardening effect is not as clearly shown in grey cast iron containing over 2 per cent silicon owing to the very much greater influence of silicon, which influence is always antagonistic to hardening.

Now this statement indicates that prior to plotting the effect of manganese upon the carbon present the percentage of manganese actually added requires correcting by deduction of the percentages used up for items (1) and (2). *The residual percentage* is then the quantity to plot against the combined carbon percentages or any other test value being compared.

In order to do this a much more complete type of chemical analysis of the sample is required than is usually given, and in the actual melting work a "blank" test melt is required to get the quantity of manganese required for item (1). This "blank" is needful since the amount of de-oxidation demanded depends so much upon the manner of melting, the quantity melted per charge and the time taken for melting.

The Time Element

There is where *the time element* enters. As is well known, the time factor in steel making is also of the utmost importance—it makes all the difference between poor tests and good tests upon any steel melt. I think that Mr. Shaw could usefully enlarge upon the need for thorough standardisation of the method of melting for research work.

This is possibly because it means too much very exact and systematic practical, and particularly analytical, work to suit the taste of the modern purely college-trained young metallurgists. They possibly realise that such research means much of hard work, slow reporting and deep thinking.

There are two important constituents in grey cast iron which you do not survey in the paper, but which ought to receive attention. These are oxygen and nitrogen.

Estimating Sulphur Percentages

For the determination of sulphur by the volumetric and the gravimetric method it is of course fully proved that in the majority of samples the two methods do not give the same results if applied directly to the drillings as received.

But it is equally proved (by personal experience) that if the sample drillings are correctly annealed prior to use in the volumetric evolution test method, the evolution and gravimetric methods *do* agree within the limits of experimental errors (the latter point must in all analytical work be honestly allowed for).

Now it is fashion to consider gravimetric methods as always giving the exact or absolutely true values. Personally I do *not* consider that this is always the case, and in the case of the gravimetric sulphur determination it is frequently not the case, for there are few quantitative manipulation methods more open to incorrect manipulation than the gravimetric determination of sulphur in cast iron.

In one case which arose some years back I found that the way the gravimetric sulphur tests were conducted necessitated these being done in the presence of silicon determinations employing the sulphuric acid method; this was leading to a continual contamination of the sulphur determinations, with the result that the percentage of sulphur represented was always much too high.

One cannot accept gravimetric methods as the perfection of methods unless they are conducted with extreme care, according to thoroughly correct schemes of analytical procedure, and in a satisfactory environment. There is too much "sloppy" analytical work turned out in present-day laboratories. In the same way the volumetric evolution method needs very careful standardisation and equally careful work.

The modern colleges turn out rather poor analysts, and modern works and foundries frequently allow too little time for first class analytical work to be performed. Further, unfortunately few of the senior men, or those

responsible for the issue of the results, take sufficient critical interest in the results put before them to prevent poor work being reported as correct.

I think this part of the paper very useful, and it ought to rouse the young metallurgical chemists at such laboratories as the B.C.I.R.A. to make a thorough investigation into the two methods.

Personally, I and one of my former assistants did a considerable amount of work on the subject during 1902-1910, and my opinion is that both analytical methods are satisfactory if conducted correctly.

I never met with *free* iron sulphide (FeS) in grey cast iron, but I have done so in the case of white pig-iron and malleablised cast iron.

In grey cast iron the sulphur is usually present as manganese sulphide (MnS), but in very soft irons it is partly present in solid solution in the ferrite, and in medium to hard irons it is also present partly in a third form which is associated with the cementite.

Influence of Phosphorus

I agree with Bolton that some of the phosphide is in solid solution in the ferrite. But he is entirely wrong when he states that it is only when the phosphorus is about 0.5 per cent that the true eutectic of phosphide of iron is produced. Dr. Stead's early work on phosphorus is much more reliable and beautifully described. Dr. Stead shows microscopical evidence that even in hematite pig-iron of the greatest purity produced in England the phosphorus is present as the eutectic. It is, of course, a case where the rate of cooling and the amount of other elements present, especially silicon and total carbon, have very great influence.

Bolton is particularly incorrect in the question of the need of high pearlite for the separation of the phosphide of iron eutectic. We have done considerable work upon this subject, and the following are two out of many tests which prove that no pearlite (or very little) is necessary in order to get the eutectic.[4]

	Extra No. 1 Grade English Foundry Pig Iron Per Cent	Extra No. 1 Grade Scotch Foundry Pig Iron Per Cent
Total carbon	2.91	3.55
Graphite	2.90	3.16
Combined carbon	Trace	0.39
Silicon	4.85	4.05
Sulphur	0.009	0.01
Manganese	0.36	1.23
Phosphorus (Total)	1.717	0.73
Phosphorus in solid solution	0.584	0.177
Phosphorus in Fe_3P (Eutectic)	1.123	0.517

[4] See also Table VI.:—"Specifications for Foundry Pig Irons," Part II. Proceedings. The British Foundrymen's Association, 1912-1913. Pages 268-304.

These results show that in the Scotch pig, with higher combined carbon, there was less phosphorus present as solid solution (in the ferrite), and that about 1/7 of the total phosphorus present was present as phosphide eutectic (Fe_3P). The above results are all percentages by weight.

It will be noticed that in the English foundry pig-iron there is no combined carbon (pearlite), and yet there is a considerable amount of both phosphide eutectic and phosphorus in solid solution.

Melting Practice.—Of course steel is not cupola melted, but on the other hand it is smelted, and the manner in which this operation is conducted and the time taken over each stage of the smelting process makes enormous differences in the chemical, mechanical and microscopical properties of the product. So there are very good parallel data concerning steel and cast iron so far as effect of melting goes, and I strongly recommend the study of both sides—they are mutually helpful, as, generally, speaking, the broader the metallurgical knowledge the sounder the deductions which can be made.

Research Suggestions

I agree with the greater part of Mr. Shaw's comments, and hope it will wake up matters. I regret I am too pressed for time to deal further with this very interesting and stimulating paper. There is a great deal of data in it which requires close examination.

A. Campion:[8] Mr. Shaw does well to draw attention to the erroneous idea that cast iron and its properties can be studied on the lines of a carbon steel. I agree that this idea has been responsible for many absurd statements, and has led to many failures and disappointments among founders who have tried to produce high-class castings by such deductions. The mistakes have largely arisen from confusing the relation of ultimate chemical analysis and physical properties, instead of considering the constitutional analysis with properties. The simile with steel can only hold from a metallographical point of view where there is some ground for considering the micro-structure as a matrix of pearlite or ferrite cut up with graphite and phosphide, but here again the composition of the pearlite or ferrite are not the same as in steel.

After all, steel can be considered as binary or ternary alloys more or less pure, but cast iron is a complex conglomerate, and we really have to deal with the resultant of a large number of factors acting at variance.

Alloying and Inherency

As regards the condemnation of the synthetic method, I presume that Mr. Shaw is referring to the theories which have been advanced by various workers from time to time based upon experiments of adding various things to a base iron, usually white iron. In that case I entirely agree with him as to the unreliability of the method. In the first place, it is practically impos-

[8] Strathview Gardens, Bearsden, Glasgow.

sible to ensure that all additions are made under precisely similar conditions, and secondly, the effects of these additions are not the same as the same quantity of the element introduced into the iron during smelting in the blast furnace. Just as brass made by the old calamine process possessed properties rather different from that made by melting together the same proportions of the constituents, or a more modern example is Monel metal when made by direct reduction of the ore gives remarkable results, but melting together iron, nickel and copper is quite unsatisfactory. I have always considered that the same thing occurs in the smelting of pig-iron; in fact, I have frequently tried to imitate a certain result by making additions to the ladle, but have always found that the result is inferior to that obtained from pig-iron of equal composition. It seems that there is some molecular change upon which inherent properties of the metal depend. For the same reason I have for many years advocated in mixing to analysis of cast iron and especially steel-mix irons that any additional manganese, chrome, etc., be added to the cupola, and not as rich alloys to the spout or ladle.

Initial Temperature Attained

Then there is another very important factor, one which to my mind has never been given sufficient attention, that is, the intial temperature, by which I mean the maximum temperature to which the metal is heated in the cupola, and the length of time of contact of the highest point. I feel certain from the results of many years' observations that the variations in this respect is responsible for many conflicting results obtained on irons cast apparently under the same conditions. Casting temperature has been shouted for years, but I do not for one moment think it is of so great importance as is usually stated. I believe it is of secondary importance to initial temperature, not simply on account of greater fluidity, but rather because it induces certain molecular conditions, and also that the question of nuclei comes into the picture; the higher it is heated the more complete is the destruction of free-carbon nuclei, and consequently the more evenly distributed and the finer is the graphite.

As regards the carbon and silicon relationship, I do not think that the modern idea of using the sum of these elements as a means of controlling high-test iron is of any value except under very, very narrow conditions, as, for instance, where one of them is fixed in amount and all other elements constant. I believe that the ratio of total carbon to silicon, coupled with the ratio of combined to graphitic carbon, has a more important bearing on the strength, etc., although Cook's formula does not express what I mean, it is empirical entirely, something much more fundamental is required.

Silicon Control

This has been carried to an absurd length, but the quotation given from Keep is perhaps hardly germane to the point, because he was not dealing with high-grade material such as we are thinking of, but only iron of the repetition order for light castings, where truth and straightness were the

only things troubled with. Strength, so long as the castings could be handled, not being considered.

The whole of the literature of the influence of elements on cast iron is unsatisfactory. It is practically impossible to compare one set of results with another owing to varying conditions of methods and material. One cannot compare the results of crucible-melted material with cupola-melted, and even with cupola-melted metal; there are the variations of cupola practice. Confining myself to my own experience with cupola metal, I have no hestitation in saying that the sulphur idea has been grossly exaggerated, and this element has been made a convenient scapegoat for unexplained ills. Actually, I believe that very low sulphur is a disadvantage, both in regard to strength and heat resistance. The best ingot moulds for large steel ingots that I ever used contained over 0.15 per cent sulphur, and I had them made with this percentage purposely, as with care in the first few heats they took on a splendid skin and had long life. The sulphur-manganese balance theory is by no means proved, and, personally, I doubt the correctness of it. Sulphur, in my opinion, seldom exists as simple sulphide of either manganese or iron, and any masses of so-called manganese sulphide act mechanically rather than chemically.

Half Per Cent Phosphorus Not Deleterious

As regards phosphorus, my views are well known. I never have advocated the reduction to under 0.1 per cent even for Diesel work; in fact, I have consistently preached that very low phosphorus was not only not necessary, but actually disadvantageous. I believe in having about 0.4 or 0.5 per cent, because at this you get maximum solidity and fluidity. I have experience of Diesel liners doing many years' service with practically 1 per cent phosphorus, and I have no experience of the brittle range which has been mentioned.

Manganese for Diesel Engine Cylinders

Manganese no doubt does cause graphitisation round about 0.5 per cent, but for high-test iron such as Diesel work, I find from experience that this percentage is insufficient. I always recommend for Diesel work over 1 per cent manganese with low silicon. Personally, I believe that temperature is responsible for the alleged manganese graphitisation, which varies with silicon and carbon content of the mixture.

Mr. Shaw refers to the good results obtained with high manganese as regards strength at high temperature and growth resistance. These results have also been obtained by me, and, in fact, I made some of the material for Donaldson's experiments. Mention is also made of the results on small bars being incomparable with thicker sections. Now, when working for the Diesel Engine Makers' Research Committee, I had cast Diesel liners to which test bars were attached and separate bars all from the same ladle. It was found that the results agreed very well on the bars cast-on and separate

with bars cut from the liners. The liners were all cut up and thoroughly tested in various ways both at normal and elevated temperatures.

The Sulphur Chill

I am in the main in agreement with Mr. Shaw's remarks regarding sulphur. There is no doubt that increasing sulphur increases the depth of chill, and also the CC. I am, however, not in agreement with the remarks about equilibrium, as it is rather inferred that the rolls which take five or six hours to set must have reached equilibrium. This, I think is quite wrong. As a matter of fact, complete equilibrium never is attained under industrial conditions. It would be necessary for solidification to be excessively slow and the temperature to be maintained near the freezing point for days or even weeks. A well-known example is 70/30 brass, which never shows a perfect structure and equilibrium under ordinary working conditions; it has to be kept at a high temperature for a very long time to reach such a state. If a simple binary solid-solution alloy is so difficult to get into a state of equilibrium, how can it be expected that so complex a material as cast iron will do so? Here we have another clue to some of the contradictory results with cast iron—various stages of equilibrium—due to varying temperatures and cooling velocities, and the number of points from which graphite deposition starts, or the question of nuclei already mentioned. These sort of things have not been considered of any importance by many students of the metal, but nevertheless I am sure they are determining factors in many cases.

Regarding the second portion of the paper, I agree thoroughly with Mr. Shaw's strictures on the insurance people referring the investigation of cast iron to steel metallurgists, who are too proud to admit their deficiency and refer it to someone who does know something of cast iron. The closing paragraphs should be put very prominently before the engineer and founder repeatedly until they cannot forget it.

HARRY M. LONGBRIDGE:[8] We notice that Part 2 of Mr. Shaw's paper contains the words "where criticism has failed" in the title. As this refers in the main to our Technical Report, we should like to point out that he has misunderstood the spirit of our report. It is in nowise written in a spirit of criticism. It primarily purports to describe examples of failures experienced by this company during the year under review. Any secondary purport lies in the offering of suggestions for the improvement of methods of design and construction of the particular part that failed, whether it is made of wrought or cast steel, cast iron, or non-ferrous material.

Reason for Absence of Cast Iron Micrographs.—We notice that on account of the absence of photo-micrographs of cast iron Mr. Shaw reaches the conclusion that we are not conversant with this subject. Granting that were so, we happen to be members of the British Cast Iron Research Association, and have facilities should we so desire for submitting any case of failure to their consulting metallurgist, from whom we are able to obtain

[8] Managing engineer to the British Engine and Electrical Insurance Co., Ltd.

a full report. As a matter of fact, in spite of our alleged lack of conversance on the subject, we find ourselves regularly asked by clients our advice with regard to design and mixings, and we have always found manufacturers in hearty co-operation with us and ready to benefit by our experience and accept our suggestions for better construction of replacement castings, and again we are daily in receipt of requests from manufacturers to overlook their drawings for new constructions, and make suggestions for their improvement. We have made many examinations of microstructures of cast iron for clients and on castings that have failed, but, as Mr. Shaw says, we have not published the photo-micrographs in our reports. The reasons for this omission are as follows:

1. Our Technical Report is primarily an engineering report, and not a metallurgical report. The matter that we choose for publication is that which we consider will interest the bulk of our readers who are not iron-founders or metallurgists. When we do publish a photo-micrograph it is done expressly to illustrate some point that a non-technical reader can readily appreciate, which he cannot with the complex structure of cast iron.

We are regularly carrying out experimental work on cast iron, with a view to correlating its properties with its microstructure, and we have carried out many experiments to determine the effects on cast iron by various heat treatments. In any conclusion, therefore, that we name, we find ourselves in a position to form our judgments with confidence. Up to now we have hardly considered such matters as being of general interest to our readers; we did, however, give some results relating to the graphitisation by corrosion, narrated in brief in our Report for 1922, pp. 63 to 66. Our report already far exceeds its original size, and it would be impossible to extend its activities to every class of metal, especially when those interested in cast iron can obtain mass information from the records of the B.C.I.R.A.

Cast Iron Microstructure Not Responsible for Failures.—2. With the exception of a faulty casting it is unusual for a failure of an ordinary grey cast iron to be due to anything faulty in the microstructure, a very different proposition from steel or other metals. This, in general, is on account of a larger factor of safety. The fault in by far the majority of cases is due to improper design or overstress. When the fault is due to faulty design it is our object to protect the manufacturer as much as possible, and we therefore refrain from giving drawings and full particulars. For this reason, though nothing may be stated in our report, we are daily altering the design of such cast iron parts as steam cylinders, pistons, fly-wheels, valve chests for pumps, bedframes, breech ends for gas and oil engines, and every kind of cast iron vessel containing steam under pressure.

In writing the report, however, we endeavour to protect manufacturers as much as possible, and as publication of drawings or fuller descriptions would make it clear who the maker was, we find ourselves forced to content ourselves by stating, "the design of the part was suitably altered to resist the stress." We only depart from this rule when we consider that the design is very culpable, such as the case Mr. Shaw reports of ribs in a turbine

casing which prevented the natural breadth of the casting. Occasionally we are able to give a brief description, such as in Case 3, 66. 31 and 32, 1926 Report, where we made a complete alteration in design, and in such cases it is usual for us to be asked by clients to supervise the design and construction of replace castings when they fear trouble.

Mr. Shaw insists that an impression is given that we consider cast iron an unreliable material. We are unaware of a single word in our reports that would lead to that conclusion being reached. This most certainly is not our opinion. A similar impression could be gained equally for any other metal.

Mr. Shaw states that many of our conclusions are open to serious doubt. We wish to point out that his only named illustration of this contention, No. 2458, is in nowise based on our investigations or is a failure experienced by this company. If Mr. Shaw refers to the title page—page 73—he will see that the case is a summarisation of a Board of Trade Report that is given without the slightest comment from ourselves. We can take no responsibility for any verdicts given there, investigations where carried out for the Board of Trade being conducted by the National Physical Laboratory.

Where Cast Iron Is Obsolete.—In reply to this point we might mention that the use of cast iron under the conditions described is entirely obsolete in this country. This is on account of numerous failures. Surely Mr. Shaw has overlooked the fact that the steam belt contains steam at the full boiler temperature and pressure. Should a turbine of this design be offered for the temperature named, it would be a matter for surprise if the maker could find an engineer in a single power station in this country who would accept it.

We make and have no charge to make against cast iron. It is, however, universally recognised to be unsuitable for use with superheated steam, the result of experience with all who have the responsibility for the running of steam plant. We think that many of Mr. Shaw's comments would be modified were he as well acquainted as we are with the running of steam-driven power stations, with the Board of Trade and Lloyd's Regulations, and with the Factory and Workshop and the Boiler Explosion Acts.

We do not know to which case Mr. Shaw refers, but examples experienced by us are numerous where contraction cracks have been formed before the casting has left the foundry. Such defects develop under the conditions of service. When their presence is discovered they are closely watched, but they sometimes run for many years before their use is deemed unsafe. We ourselves should not have classified contraction cracks as a charge against cast iron; in the absence of the reference it would appear that a more appropriate classification is improper design or improper mixing.

Mr. Shaw's words, "a wholesale condemnation of this sort." The condemnation we made lies solely in the use of cast iron for high-temperature steam. The writer of the paper gives no reference for us to refer to the case, the facts, however, we recollect. The second part of the sentence should perhaps have the words "when used with superheated steam" added to make the words, in the absence of the context, correspond with the

writer's intention when he wrote the report. The Company certainly does maintain that cast iron is not a suitable material for the purpose; nor is it aware of a single manufacturer of repute who would supply cast iron seatings for superheated steam. The trouble lies in existing valves being used for purposes for which they were not intended. For a disc valve one objection is that it is liable to graphitisation, and we have on many occasions crumbled the metal that has been sound between a finger and thumb. Our second point was only incidental, merely pointing out that while trouble is usually confined to the part itself, here the broken part caused consequential damage elsewhere, a by-no-means isolated instance.

WRITTEN DISCUSSION—SUBMITTED BY J. W. BOLTON*

This excellent paper by Mr. Shaw brings out very clearly some of the practical aspects of gray iron research. With his usual keen perception he sets forth clearly, and in a refreshingly aggressive manner, three definite practical ideas. The writer is heartily in sympathy with the general ideas set forth in the paper. However, there are a few points on which he is taking the liberty of commenting.

It is quite true that the analogy between the structure of steel and the structure of the matrix of cast iron has been sadly overworked. It has been clearly demonstrated that the usual path of fracture in gray iron is along the graphite flakes (Trans. A. F. A., Vol. 32, p. 523). Granting the greater strength of a pearlitic matrix, this matrix strength can be taken advantage of only when the amount, size and distribution of graphite flakes are proper.

The second point raised, namely, the basing of many broad generalities on results from smaller test bars, merits careful attention. The wide use of the so-called arbitration test bar has obscured the gray iron research problem —the real problem being the production of the proper metal for castings.

It is pleasant to see the sulphur bugbear chased out of the spotlight. In recent work, from 2,500 diameters up, the writer still fails to find any evidence of sulphur network.

We used to have three convenient theories, viz.:

Sulphur network.
Oxygen in the iron.
Phosphorus network.

Recent American work demonstrates the untenability of the oxygen theory, as originally promulgated (Trans. A. F. A., Vol. 33, p. 431).

Steads' work on phosphorus is a classic. Unfortunately, Messrs. Cook and Heilstone did not make proper use of his results, when advancing their theory of phosphorus network. The untenability of this theory has been shown in the Foundry—(Oct. 1, 1922, p. 787).

In the latter part of his paper, Mr. Shaw refers to a curve prepared by the writer for his paper before the Belgian Foundrymen's Association in 1925. Unfortunately, the inference from this curve is that it was made on

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an A. S. T. M. bar, and the editorial presentation suggests this. As a matter of fact, the iron cooling curve was taken from a large test bar, not the A. S. T. M. bar. This fact—not the difference in molding practice—accounts for the differences observed between the cooling rates observed by Hamasumi and the writer. The things the writer was trying to show were (a) the transformation ranges of the particular metal considered; and (b) the heating up of the sand. Apologies are due Mr. Shaw for the omission of pertinent data.

Discussion—On Research Problems of the Gray Iron Foundry

J. W. Bolton: Today we are witnessing a great revival of interest in the subject of cast iron. Perhaps this is due in certain measure to the metallurgical problems that have arisen in the last few years. To a greater degree, however, it is a business proposition; the foundry is feeling the pinch of competition, profits are diminishing. Last night we listened to a very interesting talk, a rapid fire talk in which there were several remarks that were apropos of the discussion of the subject this morning. Among these, the speaker quoted the old Grecian philosopher, Aristotle; his rule of life summed up in two words, "Know thyself." It seems to some of us that we could have a parody summed up in the few words, a rule of foundry merchandising, "Know your product." Now that sounds easy. Know your product.

You will find, as you attempt to sell iron castings against fabricated work, against steel, in some cases against certain non-ferrous alloys, that you are bumping up against engineers. An engineer usually is talking in very different terms than a foundryman. He talks in terms of fiber stress, modulus of elasticity and proportional limits, and all those things. How can we answer him?

We are going to be up against it when we go to merchandise castings and extend our market. We know that a very vast amount of research work has been done in the cast iron field; very valuable work. Unfortunately, as we study it over more and more closely, we find a great deal of it cannot be applied in our practical everyday problems. It cannot be used in our problems of merchandising, or of extending our markets. The reason for this we believe to be lack of system in research methods.

The present paper's primary object is the one thing; a plea for the extension of thorough and systematic, scientific research. Now in presenting such a plea, we cannot present it in a destructive manner; we all know that. We should give a constructive idea, maybe not a good one, but something from which to start, something on which we can build up a systematic story of a material and learn more in detail of its properties.

Dr. R. Moldenke: I said I did not feel myself competent to discuss Mr. Shaw's paper, because I had only received it this morning and had not heard very much of what he said. I might say the same of Mr. Bolton's paper, but from the presentation of the paper two thoughts come to me.

One is this, Mr. Bolton said that the two chief factors we have to deal with in cast iron are the composition and the cooling rate. That is good as far as it goes. I used to put a third idea in and that is the pouring temperature. The recent investigations of those who have gone into this high test cast iron question have shown one thing very conclusively, and that is that you have to add a third item just as important as the composition and the cooling rate, and that is the original superheat.

J. W. Bolton: All those factors are mentioned in the paper.

Dr. R. Moldenke: Well, I had not seen it, but I want to say this; that of all the work that has been done recently, you have to put a big question mark behind it, because we do not know enough about the original superheat of the metal before it was cast. The question as to correlating the tests to the properties of the castings is impractical; what we have to do is to try to get a test bar that gives a measure of the quality of the iron that goes into the casting. If we can get that, you have gone as far as you can ever go with a test bar telling what a casting will do.

J. W. Bolton: It is unfortunate that Dr. Moldenke did not have time to examine the paper more in detail, because his last comment is disproved by rather carefully taken results shown in the paper. These results happen to be our own, but there are other results published, a number of them, which tend to substantiate this same contention. In other words, would you substitute philosophizing of the old Greeks, purely theoretical, here and there just picking out something and saying it might be so and so if some certain things would happen, or would you take the method of Francis Bacon, of drawing conclusions from experimental results?

Dr. R. Moldenke: If you can take an iron and put it through the cupola and bring it out at a tremendous superheat and get twice the strength of the iron as for ordinary temperatures, it makes a tremendous difference.

J. W. Bolton: But in the ordinary run of iron, you do not get twice the strength. We have done a lot of work in a duplex furnace where we can and do run the heat way up, but we have found that for everyday foundry use, such tremendous results are not realized. Temperature is an important factor and Dr. Piwowarsky has done wonderful work, but after all, I would rather know my analysis and the size of my casting, if we are limiting it to any two things, than I would merely to get the initial temperature, though it is highly valuable. That point is mentioned particularly in the footnote of page 472.

Dr. R. Moldenke: I would rather know my composition and test bars too, but I want to try to correlate these test bars with the castings.

J. W. Bolton: That hasn't anything to do with correlating the test bar and the castings, because they are poured both from the same superheated iron.

John Shaw: The whole trend of modern practice is for a low total carbon. In cupola work in ordinary practice, this is limited to about 3

per cent total carbon. This being so, the silicon content is automatically fixed by the section of the casting and the remaining elements.

The idea of correlating the strength of the test bar to tests taken from a number of actual castings is for general purposes a new one. It is true isolated cases have been compared before. The danger is that inspectors would make no allowance between tests taken from thick and thin sections of the same casting. Mr. Bolton's previous work shows how important this point is. We know from the work done by Klingestein (mentioned in my paper) that it is possible with comparatively wide variations of composition to meet the A.S.T.M. test on the standard bar, but to maintain the result on bars cut from sections that vary much demands a very close control of composition; such that many foundries do not possess.

With regard to superheat, I agree with Mr. Bolton that the variation in the tapping temperature in good cupola practice is not great enough to have a vital effect, and that if special coke and other precautions are taken, it may affect the result. I was one who at first somewhat doubted Professor Piwowarsky's results as regards air furnace practice. We therefore tried out 12 heats without slagging off and maintained a neutral atmosphere. The time between the first and second test taken from the air furnace averaged two hours. There was a gain of ⅜ inch in depth of chill and an increase of combined carbon. The loss of total carbon was given as 0.04 per cent, silicon loss as 0.05 per cent, manganese 0.03 per cent loss, sulphur gain 0.001 per cent. All these results are within analytical error, but are given as recorded in our books.

There is one matter I would like to warn Mr. Bolton against. That is, giving results obtained by the shear test, until this method has been thoroughly tried out. The thanks of foundrymen are due to Mr. Bolton and his firm for the modification made to this test. In England a large amount of work is being done to see how far this test can be used for every day work. Thanks are particularly due to Mr. Jolley of Metro Vickers, and Mr. Pearce of the British Cast Iron Research Association. So far, our results confirm those of Elliot, Rother and Bolton. That is, that a trepanned piece out of a casting is useless unless the specimen is ground to fine limits; that the .22 inch bar is too small to give reliable results; that a .5 inch bar has given fairly concordent results when cut from the same good material, and that with a high phosphorus, high combined carbon (say 1.2 per cent) material, so far have not given results in accord with the transverse results from the same material. The results are higher and might lead to the passing of poor material. There is also the very real danger that an inspector may ask for this test to be drilled from a very thick unimportant part of a casting such as the rim of a fly wheel, or the thick flange of a turbine casing, where rigidity is of more importance than great strength. The very unimportance of the position might cause that spot to be chosen by a man with limited metallurgical knowledge.

I again thank Mr. Bolton for his paper and trust that when he has extended his investigations, we may have ample opportunity to discuss them in England next June.

J. T. MacKenzie: Concerning the tensile test and the shear test, as I see it, their field of usefulness is in such exploratory investigations of castings as Mr. Bolton has made. Now my work in pipe foundry iron has been concerned a great deal with deflection, and by that I mean relative deflection, the relation of deflection to the load, or the so-called modulus of elasticity. Now I believe you will find that if you make a transverse test on a bar that is fairly close in cooling rate to the casting involved and determine the modulus of elasticity of the transverse test, you can make the assumption without fear of any great variation in results, that your tensile test will have the same modulus of elasticity. I think you will find it in general, true that the transverse strength, tensile strength, shear strength or any related property, is due in large measure to the size and distribution of the graphite particles, whereas the transverse deflection is primarily due to its amount.

Chairman H. W. Gillett: Mr. Bolton, do you want to make a very brief reply?

J. W. Bolton: Yes, sir, I can make it very brief. In general I am in perfect agreement with Dr. Moldenke, Mr. Shaw and Mr. MacKenzie. In the beginning of the paper we made a plea for systematic research and advanced rather crude plans, and I would like to have more data, sufficient to back it up. We have to learn to walk before we can fly, and this is an attempt to do a little walking. Some of our friends would prefer to fly around a little bit first.

Corrections which should be made in the paper are:

The heading of the column of Table 6 marked "Transverse Modulus of Rupture" should be changed to read "Breaking load, pounds."

To the legend of Fig. 1 page 493, should be added a note reading, "This casting was a bar 4 inches in diameter and about 15 inches long."

A note should be added to the legend of Fig. 2, page 494, to read, "After Hatfield, *Cast Iron in the Light of Recent Research.*"

Discussion–Non-Ferrous Metals

Past-President G. H. Clamer presided as chairman of Session No. 2 on Non-Ferrous Metals. The first paper presented was Science in the Foundry by E. F. Hess. This paper will be found on pages 647 to 650. The discussion of this paper follows:

Discussion—Science in the Foundry

H. M. St. John: In our plant we use open end couples, taking the temperature of nearly every pot of metal, in many cases twice; that is, once when the metal is taken from the furnace, and on the strength of that reading the metal is cooled. Our practice is to bring the metal out forty or fifty degrees hotter than we expect to use it, then it is cooled and the temperature taken again to make sure that it is down to the desired point. This work is done by a pyrometer operator in the foundry organization who does nothing else. The breaking in of such a man is not so difficult an operation and after a little time he becomes very expert. The readings are taken to an accuracy of plus or minus ten degrees. At least that is the accuracy at which we aim. I would hesitate to say that we actually achieve an accuracy of closer than plus or minus fifteen. We have not made any scientific efforts to determine exactly what the accuracy is. The foundry temperatures are checked frequently by an exactly similar pyrometer which we keep in the laboratory and are careful to keep in good shape, the checking being done by having the foundry operator and the laboratory operator take readings in the same pot of metal at the same time, each with his own instruments. The check must be within plus or minus ten degrees, otherwise we feel that something is wrong. The necessity of so accurate a reading has been questioned. It is perfectly true that very rarely do we have to pour any castings within so narrow a temperature range as twenty degrees, and if that were the only consideration, it would not be necessary to measure close as that. However, every foundryman knows that with the ordinary run of work he must pour quite a number of molds from one pot of metal. The metal is cooling while he is pouring and in order to get good castings he must start pouring at a temperature that is not too high and must finish before the metal gets too cold. It is quite obvious that in order to pour the maximum number of molds from a pot of metal he must know fairly accurately what the temperature is to start with, also how fast the metal is going to cool. It is for that reason that most of our extreme care with temperature control is taken, in order that we can pour the largest possible number of molds from a single pot of metal and still have all of these castings poured within a pouring range which will give sound castings.

J. H. Cheetham: Has that pyrometer reader control of distributing metal to different molds of the various sizes of castings?

H. M. St. John: Not exactly, but the pyrometer reader knows where the pot of metal is going and what sort of castings it should be poured into and what the temperature should be for those castings. He does control the cooling operation and determines that the metal, when it leaves him, is correct for the casting into which it is to be poured.

Chairman G. H. Clamer: Mr. Hess in his paper emphasized the importance of accurate records, making the statement that inaccurate records are more harmful than no records at all; and that, I consider, is particularly true of pyrometers. We very, very frequently come in contact with foundrymen who are using pyrometers and depending absolutely upon their readings, and they are not exercising the care or the supervision as outlined by Mr. St. John, and in depending on these readings they are really worse off than if they had no pyrometers at all. I merely wish to hand out that word of caution in using pyrometers, that a pyrometer is a scientific instrument and must be handled in a scientific manner. Otherwise the use of pyrometers might lead to quite disastrous results.

A Member: How often must that pyrometer be calibrated?

H. M. St. John: The meters are sent to the manufacturer's plant which, fortunately for us, is in the same city. There they are cleaned and re-calibrated about once in six months. We have quite a number of these meters, so we can always spare one or two of them. It occasionally happens that our laboratory checks within that period will show that one of these meters is not behaving properly, in which case it is taken out of service and if we cannot readily find out what is wrong with it, we send it back to the manufacturer and he fixes it up.

J. M. McDonald, Jr: In regard to checking pouring temperatures with a pyrometer in a brass foundry, we started this general practice in our foundry recently, and have obtained unusually good results from it. In this connection, we have endeavored to check our foundry pyrometers against a pyrometer we hold as a standard by using the heat of the steel treating furnace for this check. We insert our foundry thermo-couple in a refractory tube, which is placed in the steel treating furnace, together with our so-called standard thermo-couple, and note the difference between our foundry instrument and our standard instrument of a temperature range approximately the same as our general pouring temperatures, which is around 2000 degrees Fahr.

The refractory tubes we have used for this purpose do not stand up. They break very easily, and are quite expensive. We have tried nickel alloy tubes, which stand a little lower temperature fairly well, but are not so satisfactory above 2000 degrees. We are looking for suggestions from anyone who has had experience with proper protective tubes for this application.

E. F. Hess: We at one time used a solid steel cylinder, about 5 inches in diameter and 12 inches long, and drilled two holes into this to a depth of about 10 inches, and of large enough bore to insert a thermo-couple in each—one being for the standard and the other for the one in question.

This cylinder was put into an electric furnace, and as the temperature was raised the instruments or couples, or both, were checked. This was found to be quite accurate, as no air currents could strike the tips. Another check could also be made when cooling.

I also put several different couples tied together without any protection into an electric furnace and closed the furnace tightly. This also is quite accurate, although radiation from the furnace to the cold end must be watched.

MR. GULICK: Our problem has been somewhat similar. Last year in starting the use of pyrometers, we found that we were able to get a tube that would stand up fairly well in the furnace and we could get a very accurate calibration. However, when we came to put it under the surface of the brass in the crucible, we were not able to get a very good or consistent check. Therefore, we have changed to the method mentioned by Mr. St. John, namely, of using additional instruments for checking the instruments in use, rather than using the laboratory electric furnace, and we find it works better.

J. M. MCDONALD: Would there not be a personal error with two men taking temperatures in the same pot, with regard to the distance they might put the instruments in the metal?

MR. GULICK: In my own experience we used three instruments, two regularly and one check, and those three operated by three different men we have taking temperatures, and temperatures must check within plus or minus twenty degrees every morning before the pyrometers are accepted for use in the metal. We find that with three different men operating, they will check. Sometimes they have to get warmed up to work, but that method does work out practically with us.

MR. BECKER: We place the tip of our thermo-couple into the metal and gradually withdraw that until it is finally out of the pot. We find that is a very accurate method.

CHAIRMAN G. H. CLAMER: Do you use a thermo-couple of large diameter wire or small diameter?

MR. BECKER: About a quarter inch in diameter.

O. W. ELLIS: To those who are using fine wires in their pyrometric readings, a method of checking roughly that can be used every time a casting has been poured is to introduce the tip into the metal in the mold and to observe when the long interval of time elapses at the time the alloy is freezing. I have tried that on certain specific alloys quite frequently and found the temperatures to check very nicely. Of course it can only be used on one specific alloy, but it does offer a method of checking up the pyrometer quite constantly.

CHAIRMAN G. H. CLAMER: In other words, you use the cooling curve method?

A MEMBER: We have two pyrometers, one in use and the other one is at the pyrometer manufacturers to be tested. Now a foundry trying to test those instruments will not do it as accurately as the pyrometer man-

ufacturer, and I think you will save money and make more money by sending some of your pyrometers in every forty days.

Discussion—Furnace Refractories for Brass Foundries

The paper by H. M. St. John, Furnace Refractories for Brass Foundries, presented next appears on pages 439 to 452, inclusive.

H. M. St. John: About two and a half years ago, the Joint Committee on Foundry Refractories established a committee on non-ferrous survey. It was the job of the committee on non-ferrous survey to investigate refractory conditions as they actually exist in the brass foundry and report on those conditions. It was not a function of the committee to carry on any investigations in the line of research or leading to any particular improvement in practice in the use of foundry refractories, but it seemed quite obvious to the committee that some of the data collected were of very general interest and that the promulgation of that data among the users of refractories might lead to improved practice. The committee went so far in its report at Detroit as to point out that these people who were getting the best results with their refractories in the foundry were using certain methods and certain precautions.

The paper is not given as a committee report, because some of this material I believe is rather controversial and it did not seem wise to have the committee make a formal report containing some of the statements that are made in this paper.

The high frequency induction type of furnace has not been discussed, because there is practically no data available as to its refractory service in actual commercial use. The low frequency induction furnace in the red brass foundries has not made such very great headway, but it is of peculiar interest in this report, for the reason that its headway has not been greater because of the problem of refractories. If refractories were available which made this furnace suitable for use in the red brass foundry, it is quite obvious that a great many more of them would be used, so that it is peculiarly of interest that a paper of this kind should mention those problems.

(Mr. St. John then gave an outline of the contents of this paper*.)

H. M. St. John: At the round table discussion of the recent meeting of the American Chemical Society, an interesting point was made in regard to the use of silicon carbide. One refractory manufacturer made the statement that, realizing the weakness of silicon carbide under certain conditions in brass furnaces, they were about ready to bring out a plastic mixture similar to the silicon carbide mixture, in which an aluminum oxide

*Editor's Note: A correction should be made in the paper as printed. The word "carborundum" is a copyrighted trade mark of the Carborundum Co. and should apply only to silicon carbide manufactured by that company.

grain would be used in place of silicon carbide grain. It was believed that the properties of this new cement, such as contraction, etc., would be equal to the aluminum and would be quite an advantage to the brass furnace under the conditions mentioned, but probably for the present somewhat more expensive.

CHAIRMAN G. H. CLAMER: An explanation of why silicon carbide is not a conductor in the slow frequency type of induction furnace is perfectly simple; that is, that in that type of furnace the voltage is so extremely low that the secondary voltage is only 5, whereas the primary voltage may be 220 or 440. That voltage is not at all in contact with the refractory, so that the only voltage encountered is 5 watts, and that is a very low voltage. Silicon carbide has a decidedly high resistance, even though it may be hot.

MR. BECKER: Speaking of electric furnaces, do I understand that the same conditions would apply to silicon carbide crucibles as in the high lead mixtures? Would there be lead at stack and introduction of silicon into the metal, to the detriment of the castings?

H. M. ST. JOHN: In a sense, quite a good deal. At one time we were using a large number of crucible furnaces and were using the silicon carbide crucible; that is the crucible to which you refer, which is largely silicon carbide in its composition. Our metal had percentages of lead up to about 10 per cent. Usually there was no silicon contamination from such a crucible. However, it did not take very much in the way of chemical action to cause contamination. For instance, even the use of borax with the charge in such a crucible would lead to an attack that would show silicon in the metal. Even those fluxes recommended as cleaners, which contain fluorspar as a base, sometimes attack the crucible violently and contaminate the metal. New crucibles are often subject to attack; during the first four or five heats the metal is seldom as good as on later heats. This point has been brought out in the paper with regard to refractories in the furnace, and it probably also applies in the case of crucibles. The crucibles contain a fluxing constituent. If the grains of silicon carbide are glazed so that there is no direct contact between the silicon carbide and the metal, there is not apt to be contamination, and that is better illustrated by the crucible than in the furnace lining. After the first four or five heats, the crucible is so thoroughly glazed that there is no direct contact and no contamination. Putting pure lead in these crucibles is an absolute failure. We used to melt up hundred pound pigs of lead in crucibles; an attempt to do that in a silicon carbide crucible is disastrous and the crucible will not last more than two or three heats.

CHAIRMAN G. H. CLAMER: A few years ago when silicon carbide refractories were first introduced, we ran into an epidemic of hard spots in our brass, spots that in machining would dull the tools, and we rather thought they were due to particles of silicon carbide that had become detached from the crucible or refractory, but we were never able to quite prove our point in that connection.

Mr. Anderson: In our castings we found that we have had considerable of that trouble, especially in a bronze mixture containing up to 30 per cent lead, and we continue to have the hard spots although we have been using the same sort of crucible for the past two years.

Chairman G. H. Clamer: Have you been able to trace that to the silicon carbide, or some other cause?

Mr. Anderson: No, although it does not happen continuously, but we run into it quite frequently.

J. R. Gill: We have traced some spots in high lead bronze which we think are due to iron and borings, and the affinity of phosphorus for the iron in making iron phosphide. These spots are little white crystals that the machinists sometimes call sand, but are more likely to be iron phosphides.

Discussion—No. 12 Aluminum Alloys

Chairman G. H. Clamer: Recently, in a little investigation we made, we found that in melting aluminum alloys in an open flame furnace, getting it to high temperature was productive of the bad results you speak of, Mr. Bossert, but if the metal was melted rapidly in such a furnace and brought just a little above the melting point and then put into another kind of furnace, an iron pot furnace, for example, in which it was out of contact with the fuel gases, and brought to the proper temperature, very much better results were obtained. Have you found that to be correct, that it is more a furnace atmosphere than a temperature effect?

T. W. Bossert: Was one of the defects porosity in the castings?

Chairman G. H. Clamer: Yes.

T. W. Bossert: The effects described in this paper are independent of furnace atmosphere, and are therefore not due to gas solution. The effects you describe, and which may be principally porosity, are of a different type than discussed in the paper.

Chairman G. H. Clamer: But that same metal, if quickly brought to the melting point and taken out of the open flame furnace and put into a furnace in which there was no contact with the flame, and then brought up to the proper temperature, when cast was perfectly sound.

T. W. Bossert: I believe it is fairly well known that the solubility of gases increases with temperature. If the metal is melted in an open flame furnace to above the melting point and is then transferred to another furnace where the metal is out of contact with the flame, it will not absorb as much gas as when heated to the same temperature in the open flame furnace.

A Member: It has been our experience that the cause of this increased shrinkage is due not so much to gases as to oxides. When the metal is overheated, the oxides form and get in between the metal crystals and weaken the bonds between the crystals. When the metal is cooled, as

described in this paper, and chilled and then re-melted, it is fluxed and when it is fluxed a portion of that oxide is usually removed and the bonds between the crystals restored. I think that most of the difficulty in the shrinkage is due to the oxides. The oxides in between the crystals decrease the tensile strength of the metal at the elevated temperatures, thereby causing what is known as either shrinkage or dross. If more laboratory work is done to perfect the method of determining the percentage of oxides and how to remove them thoroughly, it would advance the industry materially.

CHAIRMAN G. H. CLAMER: The same condition seems to be generally true with the copper alloys also; the higher the percentage of oxygen, the greater the percentage of shrinkage.

A MEMBER: Do the conclusions drawn in the paper apply to the common aluminum alloys and other alloys, such as the five per cent silicon alloy?

T. W. BOSSERT: We have not investigated that completely, but as far as we have gone it seems that it applies to the aluminum alloys as well.

DISCUSSION—RISERS, THEIR NEED AND FEEDING

The paper by R. R. Clarke on Risers, Their Need and Feeding, presented next, will be found on pages 419 to 426, inclusive.

CHAIRMAN G. H. CLAMER: One point brought out by Mr. Clarke that I think it might be well to stress a little is one I do not know that I have ever heard brought out before. It is that it frequently pays to use a higher cost mixture and cut down your molding cost. Though your metal cost may be higher, you may be saving it in your molding cost, and therefore it pays under those circumstances to use a metal cost that is higher than you ordinarily use.

MR. BECKER: We pour a good many castings, some run up to four thousand pounds. They sometimes swell in the risers but it does not hurt the castings any. Can Mr. Clarke tell me why the riser will sometimes roll up over the edges, and yet when the riser is taken off the casting will be solid?

R. R. CLARKE: We have what is known as the bleeding of a casting. This bleeding of a casting is due to the inner mass remaining in a liquid or plastic state, and then after the casting starts to freeze over the crust, contraction sets in and forces metal out through the pores of the solid crust. Oftentimes a riser will form a crust over the top and still have liquid on the inside. Now if you hasten contraction too much, you will start to squeeze that out and get the defect that you have detailed.

MR. REED: You say to put in some phosphor copper in the big risers; do you mean in a molten state or in a solid state?

R. R. CLARKE: Either; when your metal comes up in your riser, you always try to get some hot metal in there to liven it up. We have phosphor-copper in a pulverized form, put it in the riser, stir it around, and it combines to reduce any gases in the riser.

Mr. Reed: We pour a lot of metal in the very large castings, castings of a thousand pounds or so, and when we are pouring we have another ladle beside the mold with metal much warmer than is needed for the casting, to feed into the risers. I had an idea that if you put phosphor-copper in it would tend to cool the riser too much, and our purpose is to get it hotter than the casting itself.

R. R. Clarke: Well you need so very little—half an ounce for two hundred pounds of metal would suffice, and I have it on pretty good authority that the action of the phosphor-copper raises temperature in the riser. There is one thing it surely does do, it makes it more fluid. That may be because it clears it of its surface oxides, but I do not think the change of temperature from the phosphor copper going in there will be detrimental.

Chairman G. H. Clamer: It is a well known fact that over poled copper will swell. That is due to the fact that there are gases in the copper, and that same thing holds true of copper alloy, so that an over poled condition in the metal, due to the addition of the charcoal, may give you a gasified metal. The way to overcome that is to actually do the thing that we all talk against, which is to add oxygen. The copper refiner is always very careful to add just sufficient oxygen to make the top of the copper pig flat. If he carries it too far, there is a shrinkage.

Discussion–Foundry Sands

B. D. Fuller, chairman of the committee on Molding Sand Research, presided at Session No. 16 on Sand Control. The session was convened at 2 p. m. on May 17. The first to be presented was Sand Conservation and Control in a Gray Iron Jobbing Shop by T. F. Kiley. This paper will be found on pages 359 to 376, inclusive. The discussion follows:

Discussion—Sand Conservation and Control in a Gray Iron Jobbing Shop

R. F. Harrington: In reference to a statement on page 369, which refers to tables on page 370, it says, "Tables 3, 4, 5, 6 and 7 give a record of tests on five clays designated as clays A, B, C, D and E. The first three are Pennsylvania clays the fourth a bentonite, and the fifth a Vermont clay." Now in the last paragraph on page 369, the author says "Clay A is a very colloidal bentonite clay"; and immediately above that he says it is from Pennsylvania, and I wonder if that is merely an error. Of course I am not familiar with bentonite clays coming from the state of Pennsylvania.

T. F. Kiley: Clay B of Table 6 is the bentonite clay.

R. F. Harrington: Then at the bottom of page 369 it says "Clay A is a very colloidal bentonite clay"?

T. F. Kiley: That is on the drying out tests there, and refers to mixture A-1 of the table on page 371.

S. H. Cleland: Referring to the rapid drying of molding sands made with clay bond, will Mr. Kiley please say whether or not he has tried the glycerin method of correcting this tendency?

T. F. Kiley: No, we have not used that method.

S. H. Cleland: In a paper on the subject, presented during the 1927 meeting of this body, F. C. Scheiber, superintendent of the Malleable and Alloy Foundry, Erie Division of the General Electric Company, stated that through the proper use of glycerin, molds could be left open for several days without drying out detrimentally. It is stated further that the longer a mold is left open, the greater the quantity of glycerin required. This should be added to the water before the tempering operation is performed. One-half ounce to 100 pounds of sand is regular practice with Mr. Scheiber.

H. T. Preston: Mr. Kiley has brought out a point here that is important in connection with the use of clays in bonding sand and that is the mulling. I have been and I think many others have been unable to get real good results from any kind of clays in especially fine sand,

unless we mull a clay into the sand. My experience has been, especially in case of the finer sands, that on adding clays they ball up. That is something that should be watched. It has been the cause of failure in a good many cases of using clays.

A MEMBER: I would like to ask Mr. Kiley if, after having tested the permeability of a sample after it was mulled, did it show a difference in permeability than before mulling?

T. F. KILEY: I believe it would, unless it was aerated after mulling. I think if aerated, we would not notice any difference.

A MEMBER: Is there any special process for preparing a sample, as to mulling or cutting, or do you just take a sample from the heap as the molder uses it?

T. F. KILEY: It is taken just as it comes from the pile, just as the molder uses it.

A MEMBER: If the permeability is low, do you ascribe that to lack of cutting or mulling, or lack of moisture content, or the sand?

T. F. KILEY: I would say the sand, through improper cutting, mulling or tempering would affect permeability. Permeability values are, however, determined at standard relative moisture, a point brought out in this paper.

M. D. PUGH: I would like to ask Mr. Kiley if he ever tried and whether there was any difference between mixing clay with the sand practically dry as against the wet method? Do you find any difference in the result?

T. F. KILEY: The way we do it, we generally dry mull about a minute, and afterwards, during the time we are adding the water, mull for about three minutes. We think we get a better distribution in that way, just mull dry for a minute first.

A. A. GRUBB: Have you had any experience with these highly colloidal bonding materials running off on sharp mold edges more than other sands? If so, what do you do to meet the trouble?

T. F. KILEY: We have not noticed that, Mr. Grubb. You would expect the greater the dry bond strength the less trouble you would have in that respect.

A. A. GRUBB: We expect it, but that complaint is frequently made, even where the dry bonding strength was made by a compression test would indicate that the sand ought to be all right.

CHAIRMAN B. D. FULLER: In regard to the value of different bonding agents, is an agent which will burn up and disappear readily a better agent than one which is more refractory, more heat resisting, and will leave a residue in sand? There is the question. I have my own opinion, but I would like to hear somebody else's opinion on that subject.

A Member: I can conceive of one condition under which the leaving of that foreign material in the sand would help us, that is where you have very few fines. A few fines sometimes improve the properties of sand, especially its strength under a compressive load. If you have only a colloidal bond and the heat causes an accumulation of the bond and sand as larger particles, it seems to me under that condition that possibly it would do the sand good. Of course if the sand gets laden with such materials, it would be another question.

Chairman B. D. Fuller: I have reference to green sand work for iron. Is it not good practice to have a bonding agent which will easily give you, when used in small amounts, the green sand strength which you are after, particularly where you are conveying sand and handling it by machinery. Should this be a material which burns out readily, and which you can easily get rid of by cleaning. Then you could maintain your green sand strength by new additions and not leave in that sand a rough residue which would arise from the use of a highly refractory clay. I am inclined to think that in that case the sand that is not so refractory is the better sand to use. I would not say that this is true in sands for steel, but I do think it is true in respect to sand for gray iron.

Member: Can you overmull your sand, mull it too long?

T. F. Kiley: We have always tried to mull the sand a minimum of time; we have not made any experiments on mulling to determine how long we can mull the sand without injuring the properties of the sand.

Member: It seems to be our experience that with the more colloidal clays less time of mulling will give the necessary condition. That may be of value to us foundrymen in getting production out of our mullers. My experience is that the colloidal clays take effect quicker on mulling.

Discussion—Testing Sands for Durability

The second paper presented at Session No. 16 was that on Testing Sands for Durability by M. A. Blakey. This paper will be found on pages 1 to 12, inclusive.

Chairman B. D. Fuller: Are those sands rather uniform as to grade?

M. A. Blakey: We did not test for fineness. We used this durability test more or less in passing judgment on a sand to see whether it would give us the results we wanted instead of the other tests. We did not make our tests along the conventional lines. Since the paper was written the tests on samples Nos. 27, 28, 30, 31, and 32 were extended to include fifteen casts. The results are shown in Table 1. Each of these samples shows an increase in permeability after the fifteenth cast over that of the tenth.

Table 1

DURABILITY TESTS ON SYNTHETIC SANDS BONDED WITH COMMERCIAL CLAY BONDS—15 CASTS

Sample Number	Per Cent Bond Used	TEST FOR OPTIMUM WATER CONTENT							Per Cent Bond Loss at Max. Perm.	Per Cent Permeability Change	Per Cent Water When Casting
		PERCENT WATER		2	3	4	5	6			
27	5.5	Before Casting. . .	Bond Strength......	287	290	240	221	....	62	19*	
			Permeability.......	75	108	99	82	....			
		After 15th Casting	Bond Strength.	107	112	94	87	....			
			Permeability.......	115	128	119	115	....			
28	17	Before Casting. . .	Bond Strength......	....	277	252	232	217	47	37*	4
			Permeability.......	....	63	63	70	65			
		After 15th Casting	Bond Strength......	....	118	120	124	108			
			Permeability.......	....	70	90	96	88			
30	26	Before Casting....	Bond Strength......	....	....	222	214	202	41	68*	5
			Permeability.......	....	....	40	47	42			
		After 15th Casting	Bond Strength......	....	....	132	126	118			
			Permeability.......	....	....	61	79	72			
31	19	Before Casting....	Bond Strength......	....	226	215	192	177	40	None	4.5
			Permeability.......	....	73	88	77	75			
		After 15th Casting	Bond Strength......	....	110	130	124	104			
			Permeability.......	....	70	88	80	77			
32	5.5	Before Casting....	Bond Strength......	294	250	236	218	197	59	9*	4
			Permeability.......	85	88	108	90	85			
		After 15th Casting	Bond Strength......	110	99	96	92	90			
			Permeability.......	102	115	119	108	105			

*INCREASE.

Discussion—Sand Control in a Light Casting Shop

The paper by W. G. Reichert on Sand Control in a Light Casting Shop, presented at Session No. 16, will be found on pages 213 to 234, inclusive.

G. G. Brown: The statement was made by Mr. Reichert that the high grades of aluminum silicates are better bond than iron bonds. Does that mean that a high grade aluminum silicate could bond sand better than a colloidal hydroxide bond, or that a pure aluminum silicate bond, uncontaminated by iron oxide as part of the impure clay, is better than

the bond produced by an impure clay containing iron? I think there is a vast difference between the two.

W. G. REICHERT: When I speak of iron oxide bonds, I mean sands whose bond contains about fourteen per cent of iron oxide. Now sand containing fourteen per cent of iron oxide we have found to fuse at a very much lower temperature, also to burn out at a lower temperature, but we would get a greater strength with them than with sand containing about two or three per cent of iron oxide. I do not mean to disregard entirely the iron oxide, but there is little to it for certain classes of work.

G. G. BROWN: That explains the point very nicely. I am very glad to bring it out, of course. A fourteen per cent iron oxide in a sand indicates that there is a large excess of iron oxide which is not actively bonding. The point brought out is not that the iron oxide bond burns out slowly, but that an excess of iron oxide causes the sand to fuse at a lower temperature and has a deleterious effect on the bond and therefore is to be avoided, and not that a high grade aluminum silicate bond is better than an iron oxide bond.

H. T. PRESTON: On page 222 the author refers to relative fusion test. I have been interested lately in the difference between fusion and vitrification, and I wonder if the author has done any work on vitrification and if he has, what value has it been?

W. G. REICHERT: I cannot say that I have done any work on vitrification, but I have just run a fusion test which gave results that are comparable to results in the foundry. Some of these sands will fuse, others will vitrify, and others fall apart on being cooled.

H. T. PRESTON: The point I would like cleared up is, do we want the fusion point or vitrification point? Is a sand with a low fusion point a worse sand than one with a low vitrification point? In my estimation, vitrification means that the sand is in such a condition that it cannot absorb moisture any more and is therefore losing the plasticity of the clay. Is it vitrification that we are interested in or the fusion point of the clay?

W. G. REICHERT: I think you are interested in the vitrification point, but this particular method takes no account of the actual vitrification point. We heat the sand to 2350 degrees Fahr. for ten minutes, and then take that disc of sand from the oven, fracture it and look at it under a magnifying glass. According to the results obtained, we classify the sand. In other words, we do not take the vitrification or any special point in the sand.

S. H. CLELAND: We need not only high vitrification but high fusion point. High fusion would mean that the sand would not burn out of the castings and high vitrification would mean that there would not be a large amount of sand clinging to the castings. Low vitrification means that there is a tendency to form brickbats, and the progress of that condition throws the sand out of line and makes rougher castings, so I think the desired qualities are high vitrification and high fusion point too.

M. A. Blakey: It seems to me that the question of burning out brings up a point which has been overlooked in the study of sands. Organic or vegetable matter is one of the big factors in preventing the sand from burning on the casting. I can cite a number of instances as proof that the presence of organic matter helps to overcome other defects which are generally attributed to a weak or burned out sand, but for lack of time will not do so.

It is common knowledge that seacoal may be used to prevent burning on and to help peeling. Some of our best sands, Albany, for example, are rich in organic matter. Is it not possible that the reason some sands tend to burn on is due to lack of organic matter in the new sand, and that sands which are almost spent produce certain casting defects characteristic of a spent sand, because the organic matter in the sand has been burned off?

I do not intend these remarks to convey the idea that fusion point or even other things do not influence the tendency to burn on, but I do want to call your attention to the omission of this point in most discussions of molding sands.

O. W. Potter: Would that indicate that the synthetic sand would be more undesirable, not having organic matter?

M. A. Blakey: We have for several years been using reclaimed sand to make our synthetic sand. This reclaimed sand has considerable core oil, pitch binder, cereal binder and all that sort of material which comes from the core room. I can remember the time when the core binder on the grains of sand was considered to be seriously objectionable in the molding sand, but I want to tell you that we can get better results from that sand than we can get from new sand. We do not have to put as much seacoal or other organic matter in it to get the same results. Now I believe that every one of those organic materials that come from the core room, and the minute, microscopic roots of the trees and the grass that get down into our molding sand are helping us make good castings. We make a casting which show a very strong tendency to scab in a peculiar way. We have found that organic matter in the sand is essential to prevent it, and use seacoal for this purpose. One of our neighbors uses core compound to prevent a similar scab on a casting he makes.

Discussion–Foundry Coke Specifications

A. J. Tuscany presided as chairman of Session No. 11 on Foundry Coke Specifications. W. A. Selvig presented a written review of the subject and this will be found on pages 634 to 642.

CHAIRMAN A. J. TUSCANY: There have been certain proposals and suggestions made as to the possibilities in reference to specifications for foundry coke. A brief history of the development of this question is approximately as follows: The subject was first brought to the attention of a small group of foundrymen in Chicago, I believe, by a talk from one of the coke producers, the subject of his talk being Foundry Coke and the practicability of the standardization of the product as well as the standardization of the methods of testing. The matter was put up to the Department of Commerce and the American Foundrymen's Association and the American Society for Testing Materials. All of these bodies are very much interested in the subject and feel that there is a fertile field for standardization, particularly of the method of testing.

J. T. MACKENZIE: A point has occurred to me in the reconsideration of the foundry coke specification. The paper that I presented to the Institute of British Foundrymen last June showed that there was a very distinct field, especially in the new high test gray iron, for a coke that will give low carbon in the melt even while you use plenty of the coke. Take a normal by-product coke, and it is very difficult, without getting down into low coke ratios, to get below, say 2.75 or 2.5 per cent carbon, using a 13 or 14 per cent ash, beehive coke or, for that matter, a by-product coke, you can get considerably lower carbon in your iron than that. There are distinct advantages in operating a cupola with plenty of coke in it. Not the least advantage of it is that it gives you more latitude in the ability to shut down and meet the small troubles that occur.

Now there is another type of coke, coke of very low ash content. For example, here is a fellow, out on the Pacific Coast, who wants to run a little gray iron in a small cupola. He can take an oil coke that runs one-half per cent ash, 5 per cent volatile matter, and, maybe, one or one and one-half per cent sulphur, and by charging that in his cupola with steel scrap, he can melt melt his iron to give three fifty or three seventy-five carbon. I used one oil coke with 15 per cent volatile that gave me 4.3 carbon with all steel scrap.

Under the present specifications 15 per cent ash coke is out of the specification and so is coke with over 1 per cent sulphur, although a local

supply of such a coke might be highly useful in spite of these objections. A limit of 12 per cent ash means nothing to the fellow buying 9½ per cent ash by-product coke. To me the idea is to get together with the coke manufacturers and say, "How much limit do you want on ash? How much do you want on sulphur?" And the same is true for shatter, screen and other tests. When you buy 2 per cent silicon pig iron, you and the pig iron manufacturer know that it has got to be between 1.76 and 2.25 per cent silicon, or else it is rejected. There is no sense in saying everybody has to use 2 per cent silicon. Why not extend the same latitude to coke specifications? If you buy pitch coke, you do not want over ½ per cent ash and not over ½ per cent sulphur, or you are getting done. The present specification does not mean anything in these cases.

A joint committee is in process of formation to consider specifications, and I would certainly like to hear the foundrymen that are interested in coke, as it would give us a great deal of assistance in selecting that committee. I think we owe it to the American Society for Testing Materials and the American Foundrymen's Association to get at least 3 or 4 members on that joint committee who are interested in the subject.

MEMBER: We, in the main, rely upon the coke manufacturer. We buy by brands mostly, anyway, and I believe in leaving the quality to the manufacturer. We use a good bit of by-product and have held the sulphur down as low as we can, under 1 per cent. I was talking to a man from California this morning who said he was using German coke and had a good bit of trouble with the ash of the coke cutting the cupola, so I think that the nature of the ash should be one of the features we are to look after. Our firm has not started to make any of this high strength iron, but if we do, we want as good coke as we can get, low sulphur and low ash, as we don't want to cut the cupola to pieces.

R. H. WATSON: I think one of the greatest advances in coke testing that has been made in the last ten years is the combustion test which the General Motors has developed and uses. What it sets out to do, and what I really believe it does, is to show the rate of burning of different cokes in the cupola. The sample is taken from the coke at hand, burned in a furnace, the rise in temperature is noted, and the time of burning is noted. Different cokes manufactured in this country, and quite a number from abroad, have been tested in this way, and from these data the General Motors have sent out a specification for their coke to be purchased at the different plants.

Our own company carries on a standard test which has been noted here, the shatter test, also a test for porosity and standard chemical analyses.

In trying to secure a coke that will give satisfaction to the majority of our customers, we have run across many problems and learned a great many things about coals, coking time, sizing of the coals, which I feel might be of interest to foundrymen, although I realize they are interested only in a coke that meets a certain specification, not as to how

we get the coke to meet that specification. But nevertheless we find that certain coals which have a certain given geological formation have certain definite qualities as to degree of porosity, to the rate of burning to a resulting coke, and whether or not it will be brittle irrespective of shorter or longer coking time. The ash in these coals becomes a part of any coke that is made from the coal.

The chairman of the Coke Committee of the United States Steel Corporation told me last summer that in their large contract properties from which their coal was taken for the blast furnace coke at Clarendon, they have hundreds of samples of coal taken so that an analysis of the ash may be made. He told me that the most successful routine they have found was where they endeavored to keep the character of the ash the same at all times. For example, in the mixture of coal for by-product foundry coke, in which you are chiefly interested, you will very often find that your ash will approach a high limit. In the use of a coke with an ash of this character, you will oftentimes get a very viscous slag, a slag that is gummy and hard to handle in your cupola.

I would like to make the suggestion that in putting together a set of specifications, we consider chiefly these specifications which have to do with the physical character of the coke and with the combustion of the coke. If our coke is right physically and our chemical analysis is kept within the limits necessary for the work we have on hand, we cannot go very far wrong, because no matter how good our chemical analysis may be, unless the coke is strong and stands up, chemical analysis is not worth much.

E. J. Lowry: Mr. Watson is quite right when he says that the question of analysis has very little to do with the type of coke, especially as to its behavior. For instance, from the seller's point of view, he would like to sell on analysis and get by on that basis. I remember one instance when we took an agency for the selling of a coke of the Pocahantas region which was made from 100 per cent Pocahontas coal. It was coked as long as ninety-six hours. The analysis was perfect, and yet, when put in the cupola, it was so friable and broke up so small you could not get your heat up the cupola stack and you could not get the slag hot enough to get it out. The constitution of the ash in the coal was such that it would not flux readily.

Now the question of the coals used is perhaps the most important feature of the quality of coke that is made. I know of one instance where we were running 28 per cent volatile in the production of by-product coke. We made that twenty-eight volatile by the use of Pocahontas coal mixed with the West Virginia coal, which is high volatile; we were using then about 23 per cent Pocahontas coal, and the coal looked like good stuff on the shatter test, yet when we put it in the cupola it was almost worthless. It broke all to pieces because the cross fractures were increased. You will find that as you go from one type of coal to another, you will immediately change the relation of cell space and wall

structure. I find that in the usual foundry you get a better operation, get a better coke for burden carrying, when you get the ratio of cell space down as low as 48 per cent. Some of the finest beehive coke run us 50, 52 and 54 per cent, and yet you can take the by-product coke with a 48 per cent cell space and get much better melting results.

R. H. WATSON: With regard to the cell structure, you gentlemen may be interested to know that we have lately been able to take micrographs of the inside of the cell wall of the coke, and that we find you can absolutely change the character of the cell wall by a change in the coal. For example, by changing the percentage of the semi-bituminous coal, by decreasing or increasing of drafts or by the addition of more low volatile coal or certain grades of high volatile coal, you get certain definite wall structure. Take a picture of the cell, and it is not just a straight shaft, but inside of this shaft there are little pores working out from it, and you can close these up or open them by the addition of certain coals of a given density.

R. JOB: I was particularly glad to hear stressed the importance of the physical qualities of the coke. I do not know how many instances we have had at one time or another where the chemical composition was entirely good and where the practical results to the foundry were all bad. In a good many cases of that kind we found that the difficulty was simply due to the coke; in other words, the particles were so fine that the draft was lower and we were unable to get quick melting. The slow melting that occurred meant the increase of sulphur in the iron, and in that way caused a great deal of difficulty. I believe that a new specification or the best specification we could get would call particular attention to the structure of the coke, giving a simple structural test, such as the shattering test, by means of which it should be possible to determine whether or not the right structure was present in the coke. I think that is one of the most important things.

It is very well to stress the fact that the sulphur should be low. That is very important, certainly, but if you have freedom from fine particles, it will be possible to get quick melting usually, and in a case of that kind the sulphur can be very much higher and still give good results.

Those of us who have fairly long hauls on the coke, have to look out for this point particularly, because whether the car comes to us with a great deal of fine stuff in it or not makes a very great difference in our practical operation.

A MEMBER: There is one thing that ought to be investigated, and that is the form of sulphur. For instance, you can take two different cokes, one high sulphur and one low sulphur; say the high is about ninety and the low is about sixty, and the .60 coke may give more sulphur in the resulting iron than the .90 coke. I think that has an important bearing on the sulphur specifications.

WM. SAUNDERS: I have come to the conclusion that outside of the ash and sulphur, the physical construction of the coke is the most important.

The coke should be strong and in large pieces and burn readily. I think beyond that, the average foundryman is satisfied with his coke.

A MEMBER: How large should the pieces be?

WM. SAUNDERS: I do not think you can give any sizes. Very fine coke has to be used differently, of course, than the lump, but probably lumps six or eight inches in size. If it is a by-product coke, of course the pieces are quite uniform. In the beehive coke it is better to have the pieces rather large, because the foundryman breaks them up, but where he has very fine pieces, they are apt to be brittle and you have to use 10 or 15 per cent more coke in that way.

J. T. MACKENZIE: There is quite a distinction in speaking of the size of the coke, between the size as it goes into the cupola and the size it is when it gets down in the melting zone. If you take a by-product coke, which breaks up and comes to you with fines in it, and you use these fines, this statement about size is true, but for nearly a year now we have been using, with most excellent results, two inch and up from a by-product oven, instead of the three inch and up, and find better results. Now the explanation of that is that when a lump of coke does break up, it breaks into two inch and larger cubes of good coke and half inch and smaller cubes of the black ends, etc.; so that you can actually buy two inch and up and get better results in the melting zone than by buying three inch and up, because you increase your proportion of good hard coke.

R. H. WATSON: I am very glad to hear Mr. MacKenzie make that statement. It brings us back to the battle that the blast furnace men had some fifteen or twenty years ago, where we asked that coke be sized, that is cracked, and if I remember the specifications in my case it was to be put through a three inch screen or an inch and a half screen. By having coke of this kind our furnaces work more evenly.

With regard to specifications for the sizing of foundry coke, undoubtedly a sized foundry coke would be a most excellent thing. You also have to take into consideration on that score the fact of the way coke is handled at different plants. For example, if everybody unloaded their coke on a belt and it was carried up to the charging floor, you could have very much smaller sized coke, but where it is thrown out of a car onto the ground and thrown up onto a platform and carried into a bin and dropped onto a floor again, so many handlings materially reduce the size of the coke, so that we have found that the majority of our customers like to secure as large a coke as possible for use in their cupolas.

H. C. PORTER: I do not know whether I am qualified to speak on that sulphur question or not. As I have heard Mr. Lowry, it is a question of form of sulphur. In coal we have three recognized forms of sulphur present. We do not know whether these same three are present in coke or not. They are first, pyrites (iron sulphide), secondly, sulphates of lime or iron or whatever it may be, which in coal is generally in very small quantities, and third, organic combinations, that is, carbon and hydrogen and sulphur combinations.

Now, when the coal is coked, the iron pyrites break up, decompose and about half or perhaps forty or forty-five per cent of the sulphur goes out as volatile matter and the rest of it stays behind in the coke. Now whether it stays behind as a sulphide of iron or some other combination, such as a carbon sulphur combination, we do not know, but there is a possibility that the sulphur may be here in a combination of carbon and sulphur. Now the organic sulphur is largely driven off from the volatile matter, although in passing through the layers of coke in the oven, some of that may be held back, fixed, so there is room for a great deal of research work to find out what these forms of sulphur in coke are. A good many theories exist, but nothing has been absolutely determined for sure. Dr. A. W. Powell, of the Bureau of Mines, now I believe with the Koppers Company, had done a great deal of work on that subject. His findings are published and are very interesting.

I am a chemist, but I admit the importance of the physical qualities of coke. I do think that they are the most important qualities to consider for foundry use. Where the chemistry comes in is that the physical qualities depend on the chemical composition, and we have a lot to learn about the connection between the chemical composition and the physical qualities. The ash in the coal possibly has an effect on the character of the surface of these cells in the coke; in other words, it may have an effect on the combustibility. Study should be given to the question as to whether you have a surface character or a phenomenon in the ash, the mineral matter of the coal, that is affecting the rate of burning.

Now I understood Mr. MacKenzie to state that quite an important item is the question of travel of carbon into the iron. Sometimes you want the carbon to go into the iron and sometimes you do not. Now we would like to know from the scientific side, the fundamental side, just what makes the carbon in coke go into the iron. Perhaps that is tied up with this reactivity question, which is another problem that is worthy of pretty careful research.

Can we get a test for reactivity, which in other words we might call the classification properties of the carbon of the coke? To illustrate, we talk about atomic hydrogen welding, which is coming into use. We have a gas there where the molecules have been heated so high that they have been broken up into atoms, and atomic hydrogen gives very much higher temperatures in burning and your welding is done under entirely different conditions. Now when we have volatilized coke, or coke converted into gases, we may have something of a similar nature. We may have a certain power of the coke to transfer its carbon into the atomic condition and put it into the metal.

If some joint committee could organize some research work in a university laboratory or an industrial laboratory to work out a test to show reactivity, that can be repeated, so as to check up this

foundry operation as to the transfer of carbon into the iron, I believe that would be a very fine thing. A. S. T. M. Committee D-5 on Coal and Coke has considered that problem more the last two years than previously, and we realize that we are up against the need of a lot of research before we establish any method for reactivity tests.

N. A. MOORE: We are very much interested in this question of foundry coke. We only buy three raw materials that go into our foundry, that is, pig iron, coke and sand, and of the three we probably have more trouble with the coke than any other one item. What I am interested in principally is, how are you gentlemen who are proposing all these tests going to tie it up with the results we want? How are we going to know that after you make certain tests we can get certain results?

Now we have been operating a foundry for some twelve years and we have never been able to get away from the use of beehive coke. It may seem strange to make a statement like that, but we have endeavored at various times to experiment with by-product coke without satisfactory results. We have to run a melting ratio of five to one. Our cupola conditions are very closely controlled. Our product, which is piston rings, is one that requires a very careful control of our castings. We make as high as three hundred and ten thousand castings a day, and it takes only about five minutes of poor operation in the cupola to make about ten thousand poor castings, so you see this problem of coke is very serious with us.

We know certain things about beehive and by-product coke. We know that we have to run more air with the beehive coke. We know that our blast pressure goes up when we use a beehive coke. The coke used is very fragile; we throw out probably as high as twenty-five per cent of the coke and sell it to our employees because we cannot use it. We also know that if we get coke that is too big, we get into trouble.

You talk about a total fixed carbon of eighty-seven per cent maximum. We buy beehive with a fixed carbon running right around ninety-two, with an ash running around five and six per cent and sulphur running around .55. We buy it regularly with these specifications and actually get it, but the coke is not satisfactory in many respects because we cannot handle it mechanically.

Our foundry is highly mechanical in all other respects, except that we wheel our coke up with wheelbarrows. We do not like to do it but it is almost hand unloaded, because if we did not do that we would not have any coke to use when we got through with it. Accordingly I would like to have somebody explain what kind of test will show us just what kind of coke we have to use in our foundry to get the results we desire. We frankly admit that we do not know what we want in coke any more than in pig iron. We get poor pig iron but we cannot go to the pig iron manufacturers and tell them what we want because we do not know, and that is why we are interested in this development of tests.

W. A. Selvig: I wish to say in my connection with committee work and working out methods of test, that we do run into a lot of trouble on that very point, for instance, such methods of testing as the shatter test, the tumbler test and gravity test. It is easy enough in the laboratory to work out a method of test and of standardizing that method of test. Of course, it is very essential that such empirical method of testing be standardized so that everybody will get the same results, but when you come to correlate the results of these tests with actual operating conditions, you are up against a much larger problem, because it is something the laboratory men cannot do. The laboratory man makes his tests and standardizes these methods of testing, and then he hopes that the operating people will take these tests and give him a line on how they correlate with the operating conditions. I suppose that in order to do the thing right, a good deal of large scale experimental work would have to be done, if you were going to really and honestly correlate all these physical tests of coke with the performance of the coke in the cupola.

I was interested in the current issue of the British publication, Fuel, in which Dr. Wheeler has an article covering some experimental work done at Sheffield University, not in cupola practice but in the use of various cokes in making crucible steel. They claim over there that they have had very good results with a particular beehive coke. A certain by-product coke they used did not give satisfactory results. The beehive coke they used gave a higher combustion temperature. They made porosity tests on these cokes and found that this particular beehive coke which they were using had a uniform porosity throughout the coke. They made these same porosity tests on the particular by-product coke they were using and found a big variation in the porosity from one end of the coke pile to the other. I think the end next to the oven walls had about forty per cent cell space, and using the same method of determination at the inner end it was twenty or twenty-two, showing a marked difference in porosity. They also make the interesting claim that with the beehive and by-product coke made from the same coal, they get a good deal more trouble due to slagging with the by-product coke, which was explained by the fact that their temperatures were much less with this particular by-product coke. The temperature was not high enough to cause the ash to melt and become fluid so it could run off through the grates. The by-product coke ash formed a very bad clinker and obstructed their air flow. The beehive coke apparently gave a good deal higher temperature, sufficient to melt the ash and let it run out through the grates without giving any trouble.

Listening to the discussion, it seems as if the outlook is quite hopeful for this committee of which Mr. MacKenzie has kindly consented to act as chairman. It would seem as if we ought to be able to get sufficient information to prepare specifications covering simple physical tests without waiting the long time that may be necessary to conduct this fundamental

research on reactivity, combustibility, or whatever you want to call it, but I think that should be done in order to get the fundamental information.

H. C. PORTER: I suggest that the committee ought perhaps to handle this as a questionnaire; draw up certain questions, not too lengthy, to be sent to the foundrymen, and ask them for any existing specifications they have on what they consider is desirable for their purposes in the line of foundry coke. Then we will know what to strive for.

J. T. MACKENZIE: Probably the committee should consider the properties of the cokes that are available and indicate what the particular application is. For instance, if a man wants high temperatures and wants to use a lot of steel scrap and still keep his carbon, then he wants a low ash reactive coke. If he wants high temperatures and wants to run low carbon, then high ash, non-reactive coke would be indicated. For instance, a paper just out from the British Iron and Steel Institute gives beehive coke a reactivity of 43, compared with a by-product coke at 100; so you can see that I believe that the absorption of carbon is tied in correctly with reactivity. You must remember that this is a total reactivity, which would be the function not only of the reactivity of the coal particles, but also the types of coke, because the time of contact comes in there and also the temperature of burning.

It seems to me that the committee could get useful ideas to the foundrymen lots better by working from that end, rather than by trying to go to the foundrymen and asking what they want, because many of them do not know.

Discussion–Materials Handling

L. L. Anthes presided as chairman of Session No. 17 on Materials Handling. This session convened at 10:00 a. m. on Friday, May 18. The first paper presented was by E. F. Scott on Materials Handling and Its Relationship to Building Plans. This paper will be found* on pages 153 to 170.

Discussion—Materials Handling and Its Relationship to Building Plans

Chairman L. L. Anthes: The fact is being borne home more and more every day that very often for a comparatively small capital outlay, very material returns are gained in the matter of labor saving, and if you have watched the progress of foundries for the last ten or fifteen years, you find that some of the most advanced economies have been effected through the installation of the proper material handling equipment.

R. E. Kennedy: The larger plants naturally go to the use of continous molding systems, but the tendency will be more need for the smaller units which can be put in. Will that affect your building plans? Do you think it is feasible to have these smaller continuous sand handling units in smaller jobbing plants?

E. F. Scott: Yes, I think so. I think the tendency will be to eliminate as much labor as possible. Of course the jobbing foundry has not gone very far that way. I believe the material handling men will study that problem carefully and work out ways and means to accomplish those things. Of course where we have a miscellaneous number of castings to make, etc., the problem is more complex than in a big production plant.

R. E. Kennedy: A firm making piston rings bought for a foundry a building which had been a rubber tire factory, of very good construction, two stories, both stories very high, and they have the casting and melting on the upper floor. They are adding a third floor in between. They divided the first floor up into two floors and are up against a proposition of how best to put that floor in and yet get the continuous materials handling all the way through.

E. F. Scott: In case of buying an old building for a specific manufacturing purpose, ninety-nine times out of a hundred it is better to build a new building, because when you add up all the money you spend on revamping an old building, it is not very much less than building a new building. That has been proved in a good many cases and a lot of manufacturers are beginning to see that idea.

If you can buy a building cheap and it has all the facilities you need, it may pay to buy the old building and change it over slightly. In a good many cases, however, it does not pay to develop new manufacturing plants out of old plants, especially as they are developed nowadays.

*Editor's Note: Attention is called to an error in the paper as printed. The legend for Figs. 2 and 3 should be transposed.

J. H. Hough: Is there any set of conditions or type of casting that determine the type of plant, whether it is to be spread all over several acres or start at the top and work down?

E. F. Scott: I do not think the kind of casting determines that so much as other factors; what is the price of land and where is the plant to be located? In connection with a manufacturing plant where they have a plot of ground of just so much area and they want to build in conjunction with it, why, it possibly pays to build a multi-story plant instead of going out to some detached place and building a single story plant; so I think it is more or less of a local problem and it is not so much the kind of casting, although of course it would not be logical to make very big castings in a multi-story plant.

Chairman L. L. Anthes: Any of you who attended the session on cupola yesterday afternoon undoubtedly heard the description of the Maytag foundry at Newton, Iowa. The Maytag foundry casts approximately a hundred tons of metal a day, and it is built on the multi-story principle. I believe their cupola is about two stories above the ground floor. Of course the materials handling layout for a plant of that description would be entirely different to the layout of a plant on one floor; you have a vertical problem as against a horizontal problem.

Discussion—Determining Returns from Materials Handling Equipment

The paper by J. J. Hartley was next presented. This paper will be found on pages 281 to 286. The title of the paper is Determining Returns from Materials Handling Equipment.

Chairman L. L. Anthes: It may be noticeable to those who follow modern advertising that a great deal of advertising takes into account not only material economies but humanitarian economies. In the advertising of articles like vacuum cleaners and things to take care of household drudgery, you may notice that a great deal of advertising is done along that line, appealing to the housewife. Possibly unfortunately the same appeal is not made in the matter of foundry equipment. The question of economy is stressed there. You may take into account the question of putting in some equipment that will take the drudgery out of foundry work. The installation of that equipment may not pay any material dividend, but it has the humanitarian aspect and it takes the drudgery away from your foundry work and may make your molders and your help generally more satisfied with their jobs. There is considerable of that done by humanitarian foundrymen and other manufacturers all over the country. I think we should not only look at it from the material standpoint, but also the humanitarian psychological effect that it will have on your production.

J. H. Cheetham: I would like to ask if there has been any comparison with the same class of work by the same company; whether it is more economical to operate a gravity handling system, considering the labor

cost of output per ton? Has this test been made by any companies to see whether it is really the cheaper way to produce, disregarding the building or the property?

J. J. HARTLEY: I believe that that is a particular problem. Our company has a similar problem right now. It has been determined that it would be economical to make part of our work in the foundry on a gravity or multi-story system and we plan to handle it this way.

J. H. CHEETHAM: I had reference to the labor-saving standpoint only.

J. J. HARTLEY: It would depend entirely on the class of work.

J. H. CHEETHAM: Pertaining to brass foundries, how would you be able to handle various metals on the continuous mold conveyor? Has that ever been solved? In other words, has there been any method devised to use either varied colored flasks or tags or something of the kind? What seems to be involved in every condition that comes up is how are you going to handle different metals and different grades of temperature castings? In the brass business you have a more difficult problem than in iron, because in brass castings you have very thin work and some heavy work, and if they are all on the same conveyor, the metal for one would not do for the other. Has that problem been solved satisfactorily? If this problem was given more thought, such installations might receive more attention from some of the brass foundries.

J. J. HARTLEY: That has been taken care of in a couple of installations by tagging; and in another case I know of they have varied colored trays on their continuous mold conveyor. It is somewhat of a handicap, though, from a production standpoint to have a molder place his mold on a particular colored tray; he sometimes has to wait for his color to come along.

J. H. CHEETHAM: There is another thing; where you have one local pouring station, you may be melting a special metal that you do not get continuously. Has there been any method solved to sidetrack those molds so that they can wait for that metal?

J. J. HARTLEY: I have heard of one installation using an overhead pendulous type with a swivel tray, large enough to take several molds, and they would store certain work on the back side of this until they had a heat from the right metal, and swing this tray around till it came through the pouring zone for that particular metal. It is merely a storage in the meantime. That, of course, it a handicap to high production.

J. H. CHEETHAM: It does not seem to have been figured out, and for that reason is to some extent jeopardizing installation in a great many places where they would like to use it.

M. W. POTTS: I would like to make an answer to this gentleman's question, that I have found in working out not only foundry problems but other production problems frequently. If you will get your production man or the schedule man to look over this schedule, he can change that schedule around so that you do not get such an assortment of castings going through in a short period. This might not be your case, but I am

mentioning it as a point, and if you will look over this miscellaneous assortment that is coming to you every day, you might be able to bunch it every other day. That is not so much a conveyor problem as it is a production problem. The conveyor will handle the material and get it to the proper pouring zone and take it away to the shakeout, and do all that, but it cannot sort your work so it comes down to being a production problem. The conveyor man or salesman or conveyor engineer is not qualified unless he spends weeks in your plant engineering your particular production problem to tell you on one visitation or on two what you should do, but I find that close cooperation with the plant man will invariably solve these little kinks and then, if the plant man is willing to change his idea a little bit, a satisfactory system can be worked out.

Discussion—What Materials Handling Equipment Can Do for the Jobbing Foundry

W. B. Marshall presented his paper, What Materials Handling Equipment Can Do for the Jobbing Foundry. This will be found on pages 595 to 600.

R. E. Kennedy: Can any statement be made as to what at present is the smallest tonnage of sand that it pays to handle by mechanical conveyors?

W. B. Marshall: Judging from my own experiences, I would say about thirty tons an hour for a continuous system. This is about the smallest unit I have come in contact with. Some one else may have other experience, but in individual units there is really no limit to the size, it is entirely a matter of application. Some conditions might be peculiar and bring the unit size down to a very small quantity.

Iron castings require about nine tons of sand to a ton of castings, and steel six tons of sand to a ton of castings. There may be excess of capacity in the system, but when I say a thirty ton system, my meaning is that that is the capacity of the molding machines, approximately thirty tons of sand per hour.

J. J. Hartley: The smallest systems I have heard of were about twenty tons an hour. They are usually in non-ferrous foundries, and may be the unit is run intermittently. I know of one case where a unit is somewhat oversized and only operates about two hours a day.

F. D. Campbell: Mr. Marshall, in mentioning thirty tons, is right in this way: if you want to distribute sand or work a sand handling plant, equipment for anything under thirty tons does not pay to put it up, because a thirty ton unit would be just as cheap as a twenty ton unit or sixteen tons or ten. A foundryman who anticipates expansion in his plant might as well put up a thirty ton unit if he only needs ten, because he may be able to develop the work in his foundry and eventually use up to that capacity.

The beginning of such a development might be the loading of a mill with a skip hoist. It may then be decided that overhead sand to the

molders would reduce the cost. Then the manager might start in by putting in an elevator and a belt, a type of equipment handling a few hoppers for three or four molding machines. After he got this all to working and found that he was reducing his cost, he might extend this belt conveyor down the line and rearrange his molding machines and put in three or four more units. Any foundryman who puts in overhead sand equipment for four units, will soon have it all over his plant as it will soon be demonstrated to him that he cannot do otherwise.

Mr. Marshall warns us that the trend is sometimes toward over-equipping for conditioning. We found that sand heaps around the foundry took up a lot of room and wasted floor space. We decided that we would not have any sand heaps; we decided that we would have all fine clean sand, just one kind, go in the molds. Having cleaned up all the sand by magnetic separation, and vacuum cleaning to remove the dust, we found that we only had to do about one-tenth the work on the sand that we originally did, and the equipment already existing in the plant was re-arranged and material handling equipment added to it. Equipment that had been used to condition fourteen to sixteen tons of sand an hour will now condition fifty tons with perfect ease, and where it formerly required two men, one man does it all now. Laboratory control of the sand has put it in a far more perfect condition than it ever was before.

A MEMBER: On your steel foundry work, are you putting all your sand through the system, both the backing and facing sand, or just the facing sand?

F. D. CAMPBELL: Nothing but the facing sand, for we use only the one sand. It is the trend in the steel foundries to do away with the backing sand and use all facing sand. When steel foundries will use the one sand they will get rid of a lot of trouble.

I will give you an example of what it meant in the way of concentration of space. We apparently were faced with the need for additional floor space three years ago, and were planning on it. But we began the mechanization of the foundry, as we call it, clear through to the point where our castings go out the door through the cleaning room, and now we have no need for additional floor space. That is what the change accomplished in the economy of space through mechanical handling equipment properly worked out.

W. F. GRAHAM: In the endeavor to increase production and attain greater efficiency in foundry operation, a great deal of emphasis is being placed now on mechanical contrivances, on conveying the metal, on handling and conditioning the sand, handling the castings after they have been shaken out and on treating the foundry sand to obtain greater life in the heap; but my thought in connection with the matter is that there is too little emphasis laid on the strictly engineering side of the problem. The foundry man, of necessity, is not a trained engineer, and a great many of the technical people connected with the foundry are not trained on strictly engineering lines. Production people do not necessarily have that training. I think

that the problem should be approached from the engineering standpoint of the cost of useful work, if I may express it that way. Of course, the other problems in connection with the metal and the sand and the question of production have a bearing.

We have found in our plant that it is possible to almost completely translate the work into automatic equipment, but in some ways it does not necessarily mean a saving. Now, as our works manager expressed it a number of times, there is still lots of work left for the wheelbarrow, lots of work that can be still done with the shovel. I mean by that, that if you have a man who is available to do a certain job, for instance, loading sand in a muller, and he has a certain amount of spare time, one hour a day, it may look all very nice to have wheels go around and conveyors to lift that sand into the machine, but it is a rather costly operation; this man can probably do it without any increase in indirect labor charge.

There is another aspect to the problem. If the operation can be made entirely mechanical and subject to a strictly laboratory check, it is very desirable, but foundry operations depend so much on the human factor, and where operation is made so mechanical that the attention of the people is no longer directed to that operation, errors creep in that may become cumulative and cause considerable trouble. At least, we have found that to be the case; the psychological aspect of a too intensive mechanical equipment.

I do not want you to take my remarks as being a wet blanket on this discussion of materials handling, because I personally am heartily in favor of it and our company is also. We are spending a lot of money in converting our foundry at the present time into a really mechanical operation, but these two points I want to emphasize again; first, what is the cost of the useful work that is done? Not the useless work; and is it proper to detract from the responsibility of the people operating the foundry? In the last analysis, they are the men responsible for both the quantity and the quality of the product.

F. D. Campbell: I think that we can place a limit on that by an organization working around in a different way. Sand in our plant is entirely divorced for the foundry production, as far as the control goes. We have a maintenance crew which operates that entire system. They are responsible for the delivery of the sand going to the molders, but they are directly under the control of the laboratory. The laboratory has, four times a day, tests from all parts of the foundry. The maintenance crew have their hourly tests of the sand. Then there is a laison between the laboratory and the engineers who keep the system in working order.

W. F. Graham: We have quite a technical force, but the thought we are trying to convey to our shop men is that they share the responsibility, from the foreman down to the workman. When you relieve a man of his proper responsibility, you take away from him the incentive to do good work and are beginning to get out on pretty thin ice. You are still dealing with human beings, not machines.

F. D. CAMPBELL: We found that we had to take the sand control out of the hands of the production department.

W. F. GRAHAM: We are trying to shove it back there.

F. D. CAMPBELL: When I say that, I will qualify that in this way; we do not mean that the production department has lost any interest in it at all; they work along in a fine and happy spirit to achieve the proper results, but we have relieved them of the burden of watching the sand; we are having it come to them uniform and better controlled and they like that and appreciate it and it has worked out splendidly that way.

W. F. GRAHAM: I want to say this; we operate two foundries; a brass foundry and a malleable foundry, and we found that the setup in those two foundries was entirely different; and right in the same plant, as regards the sand problem, the psychology is entirely different, due entirely to the personal factor.

M. W. POTTS: In both Mr. Marshall's and Mr. Hartley's paper, they have brought out the fact of saving, money saving, and I notice the particular item of one hundred per cent saving in a year. That is a ridiculous item. Material handling people themselves are responsible for this theory of a quick return. It is not only in the foundry industry that it is being looked for, but in other industries. I want to get on record, more as a material handling man than as a foundryman, that to look for one hundred per cent return is very nice, but if you always use that figure as your deciding factor in making a decision to buy material handling equipment, you are likely not to start to put any in.

If any of us could buy a good investment stock or bond, and get ten per cent on our money, we would go out and borrow money and pay five per cent to get the money to purchase the investment, and we would be satisfied with the additional five per cent for our services. Material handling equipment that will pay for itself in four years is a good investment, and the item I take into consideration in making this statement more than depreciation is obsolescence.

I do not think any foundryman is going to spend ten thousand dollars if he feels that his plant is going to be obsolete in four or five years and I do not think any foundryman is foolish enough to spend it even if he could get it all back in one year, if he felt that it is going to be obsolete in one year. What I want to bring out is the falsity of this idea that the equipment has to pay for itself in one year's time.

Let us look at the matter rationally; consider this from all points, and especially from the standpoint of the foundryman. Don't hold off just because you cannot get one hundred per cent return; it will pay you if you take it on a four or five year period, and ten years later you will be running some of that same equipment. I have some material handling equipment that has been in operation in some foundries ten or twelve years and is still going strong.

There is another point on which foundrymen are ridiculous. They feel that because they put the machinery in, it is going to run constantly

without mechanical supervision. They are constantly checking up their patterns and repairing their cupolas, but when they put in material handling equipment, they forget to allow a certain item for maintenance. You have to have a man who knows how to maintain the equipment. If you forget to take up a bucket elevator, you are likely to break it down in the middle of a run; if you don't watch your belt, you are likely to strip one off the buckets and if you don't watch your gears, you are likely to break them; but one man can maintain a considerable amount of conveying equipment and it pays to have that one man.

F. D. CAMPBELL: Matters of direct and indirect benefit in return for these investments generally are matters for individual consideration on the job. I will cite an example. The department of a large manufacturing plant was condensed by rearrangement and the incidental employment of material handling equipment. Before the project was inaugurated, all figures pointed to about thirty-five per cent return after all items were put in, depreciation and the usual conventional items. After having done this first installation they saw how other departments could be rearranged so the space that was vacated by this concentration, or condensing, was filled in by other items. The return at factory cost based on ten per cent filled into the space vacated finally worked out within two years' time to be five times the cost of the original project annually. Now nobody could have thought of that; that is indirect, that is a matter of development and use. I have known systems to be put up where the return for the first year was almost nothing; for the second year it was better and for the third it was better still. So it is hard to say what you can get back. You can make any kind of claim you want to, but I think the claim can be made to the prospective purchaser that he can expect increasing returns as he becomes more familiar and knows how to more intelligently employ that equipment that he has placed in his plant.

C. B. CROCKETT: Referring to Mr. Graham's remarks concerning the employment of men who would probably have to be kept on the payroll even if mechanical equipment were purchased—of course an ideal condition in a foundry would be to have one hundred per cent of the men employed in a useful work the entire time. But everyone knows there's a certain factor in there, you might call it slip, between the useful work and the total time. If mechanical equipment were going to increase that percentage of slip, you can eventually probably take men from your payroll. In other words, if you have a man who only does one hour of work a day and still has to stay on the payroll after a certain machine has been installed, there may be another man in a similar position and by the installation of another machine in some other part of the plant, these two jobs might eventually be combined. I believe you always have to increase the number of non-productive men in the plant to a certain point before you can eliminate those men. The only way you can do is to run for a certain time temporarily in a condition that Mr. Graham speaks about.

F. D. Campbell: That situation is taken care of in the foundry; for instance, men pouring metal on a piece rate per mold, and who work at other items of common labor, are so scheduled in a period during the day that as soon as they are through with their metal, they go back to their work on the hourly rate. Thus we get a very thin spread of a minimum number of individuals with a highly useful employment. For a project that is anticipated, the engineering department interprets everything in terms of useful work and the investment is only permitted to go as far as the unit or any item of useful work can be considered.

C. S. Schroeder: With reference to the statement regarding the return from material handling investment which would pay, I think one of the factors a good many people lose sight of is the fact that business may not always be at the same level, it may not increase in proportion as anticipated, and on account of that, I think they expect a larger return than twenty-five per cent. As a matter of fact, there are very few manufacturing organizations who will run as low a margin as twenty-five per cent. The obsolescence on the equipment is probably due to a change in product or to, probably, expansion. I don't think that twenty-five per cent is even enough.

M. W. Potts: If you are on such thin ice that you have to get a hundred per cent return, don't put it in. If you cannot pay for it over a four year period you are putting in something you might have to rip out next year, and it all costs you money. If you can get it on a twenty-five per cent basis and then are fortunate enough to get one hundred per cent return, you are making good money. Now if you will look at it on a four year basis, you must put in equipment that will be flexible enough that it can be turned around and used for something else. A lot of people think because they are putting in a sand handling plant that it always has to conform to that particular layout. It might be that they will want to change over their type of molding machine and want to get the multiple molding machine. If they do, they will find that the conveying equipment is so flexible that they can tear it down and rebuild it and not lose over ten per cent. They can take the sand handling equipment over from the east end of the foundry and stick it up in the middle, and it will cost them about twenty-five per cent to move the arrangement. If they originally try an electric truck, they might find that their production increased so that it pays to put in a conveyor, but they will find another use for that electric truck.

The point I want to get away from is that we should not look for that one hundred per cent return and should realize how flexible all types of material handling equipment are. It is very flexible, more flexible than a pattern or a cupola. When we realize this we will be getting somewhere on the making of small installations and the foundryman will find that he is getting his saving. If we hold up a hundred per cent saving to him, it will be like when a man stands on the street corner and offers to sell you a five dollar bill for a dollar. You will ask, "What is the matter

with it?" I don't blame the foundrymen for feeling the same toward some equipment salesmen.

F. D. Campbell: I think the prophecy can be made that as engineering is incorporated in our foundries, you can expect the support of the engineers to properly determine what is a conservative expectation of return, and that they will in some cases, on a twenty-five per cent return, approve a problem as being all right, on the basis that they can increase it by their own work and develop it after they get it in, because that has been proved in so many cases.

M. W. Potts: I do not care how they get around to prove it, as long as they get to it.

F. D. Campbell: Well, they will assist all right. The only item which they would permit to be used as an economic specification for approving the project in the case I cited was a certain amount of floor space vacated. Not one item in labor was permitted to go in the analysis presented for economic classification, but on that one item alone is where they get five times the return, not counting the increased fluidity of motion and the so many other things that they could not express in dollars and cents, until the system had been in operation two or three years.

C. S. Crockett: I can bear out what Mr. Campbell says from an experience I have had in the electric light and power industry, which is a highly engineered industry. It is, in addition, under the scrutiny of the Public Service Commission. They figure planning an improvement on the basis of borrowed money. If they can show that an improvement will earn six per cent or anything above six per cent on their capital investment, the Public Service Commission will allow them to make that expenditure and borrow the necessary capital, but it will not allow them to charge off equipment on the basis of obsolescence. Electrical equipment changes very rapidly, and increased efficiency often makes it advisable to install new equipment. They, however, have to figure the junk value of the equipment which they are now using and charge that off, and if they can show sufficient increased economy, they can borrow the capital necessary to restore new equipment. They do not consider it fair, however, to charge off obsolescence as depreciation; in other words, the depreciation has to be charged on the actual life of the equipment rather than the possibility in the future of obsolescence, and it is only the increased efficiency of the new machinery which allows them to retire old equipment from obsolescence. Whether that can be applied to the foundry industry, I do not know.

Chairman Anthes: There is no question but that basis can be applied to any big industry or any big public utility. As you know in a matter of accounting and financing, it is hardly reasonable to expect a hundred per cent capital return in one year's time, and I think that all you gentlemen who run your business on up to date methods write off so much every year for depreciation. Many plants give the life of their equipment as twenty years, others as ten years and others less, and write it off accordingly. Many people write off ten per cent per annum, and that really is

building up the reserve for replacement. You can analyze it any way you wish. The man who is in a highly competitive business today in industry must watch the changes very closely, for changes occurring in a space of five or six months, and very often possibly less than that, are going to determine the factor of success or failure. The American man in industry today must keep his eye open all the time and keep absolutely abreast of the times.

Discussion—The Electric Truck and Foundry Materials Handling

The paper by H. J. Dorus and C. S. Schroeder was presented by Mr. Schroeder, and will be found on pages 171 to 190.

C. S. Schroeder: This paper has been prepared with a view particularly to present information to foundry operators which will serve as a guide in selecting the means of handling the various types of materials found in the average foundry. We have made no direct comparison in cost of operation between electric industrial trucks or other modern machinery, but have rather tried to show what an industrial truck can do and what they have done in actual practice, so that these results and operations may be compared with other projected schemes of handling.

We recognize the fact that the industrial truck will not solve all of the problems that arise, and have therefore attempted to point out the specific type of problem that is capable of being solved by the installation of a trucking system. When comparing electric trucks to other means of material-handling equipment, the fact that the truck is capable of a very wide range of uses, besides the one for which the truck was initially purchased, is a factor of considerable importance in certain industries. Where the product of a foundry is subject to variations in quantity, or in size and shape of material manufactured, it is frequently found that built-in conveying systems must be rearranged to provide for the change in product. For the trucks a program of expansion or changes, mentioned, can usually take place without obsolescence of any of the trucking equipment. Possibly additional machines would be required to handle a peculiar shaped casting or an unusually heavy load, but never have we heard of a case where machines were actually scrapped before they were worn out.

In actual experience we have found that after a truck has been bought for some specific use in the foundry, many other new uses make themselves evident. Workmen and foremen observing the actual operation of the machine on one function of the material-handling scheme, are often quick to recognize its value for different classes of work. For illustration, we have often found that for a period of about a year, a battery of a certain size will be thoroughly capable of doing all of the work given it by the customer. After this time, due to the large number of added uses, we frequently find that it is necessary to install a battery of larger capacity to take care of the additional work that the truck has been assigned to, even though the original battery had plenty of capacity

to more than take care of the work for which it was originally purchased. This condition clearly emphasizes the fact that the trucks can be adapted to many jobs besides those which are used as a basis for figuring the probable savings that could be made.

Each of the various operations which are fundamental to every foundry has been treated as a distinct and separate operation, although in actual practice, especially in smaller foundries, many of these operations may be performed by only one truck. Wherever possible, reference has been made to the approximate tonnage that may be carried by one truck if run continuously on the work outlined. In foundries where the tonnage would not permit the use of a truck continuously on one of these operations, it will be possible to determine approximately what proportion of percentage of the day will be required and in this way determine the extent of usefulness of the equipment. A careful study allows us to determine very closely the cost of doing the work with existing equipment. We know approximately the number of laborers required for each of the operations of material handling and if material handling is done by direct labor or productive labor at any stage it is well worth while to have a study made to show what percentage of productive labor is lost or wasted in material handling. This may sometimes involve a more complex study, but it certainly is economy to have low-priced labor for material handling and allow skilled productive labor to devote all its time to making product. In many plants, we have found two, three or four men who are directly employed for material-handling purposes, but on making a further analysis, it was found that a fair percentage of the time of practically all of their molders was devoted to conveying material around the plant. Inasmuch as many men were employed in productive work, this small percentage represented a cost of material handling more than twice that which might be reflected by only considering the material-handling gang.

We urge all those responsible to more carefully investigate this possibility of using a fuller percentage of the skilled mechanics' time on productive work.

To permit a comparison of truck costs with hand labor, the Industrial Truck Association has established, as a result of actual experience, a fixed charge for the operation of the equipment. This fixed charge, which is $4.00 per day or 50c per hour, will cover the cost of maintenance, depreciation, interest on investment and other charges which amply cover all the expenses for operating a machine of the self-loading or elevating type. It is obvious, therefore, that cost of operating a truck as a piece of machinery is less than the cost of one laborer, and on the usual job the cost will be found to run considerably less than the figures given.

Mr. Crockett: It is generally true that men in the industry pay more attention to the handling of operations which are peculiar to or inseparable from the actual process of the industry, and that they neglect what might be called the miscellaneous handling, the handling of goods, shipping of goods, the handling of materials to and from stores which are not

essentially a part of the foundry industry. The point I want to make is that of this miscellaneous movement of materials—lessons can be learned from any industry, and that you do not have to limit yourself to developing it within the industry. I had a recent experience with the canning industry, where everything in connection with the process of work was highly specialized and hand labor was used almost without exception for this miscellaneous movement of material, and an interesting comparison could be drawn between the handling of cartons or cases and boxes or barrels; trucks used in the radio industry or the milling industry, or all those other industries which were in no way allowed or comparable to the canning industry; it might be possible for a plant executive to analyze his movements and discover what movement was peculiar to the foundry industry and what could be termed a general movement of material, and then look at industries which had a similar problem.

C. S. Schroeder: In connection with Mr. Crockett's remarks, there is one incident which is very interesting to us. It was a large foundry making valves and fittings, and their molding equipment and system was very modern; their tonnage was large and they had a great many pieces of a given pattern. They had continuous pouring, sand coming from above, shakeout grates and everything was of the first order; but until fairly recently they had no mechanical way of taking their castings to the tumbling barrels. On that job it later developed that they raised their tumbling barrels so that a skid or lift truck could be placed under the barrel and an inclined platform was placed above the barrel. A very high lift type of truck would run the skids to this inclined platform above the barrel, probably eight or nine feet in the air, and would deposit a skid on the incline. A hinged gate on the lower end of the skid made it possible to empty the castings into the tumbling barrel when desired. The loaded skid of untumbled castings would be stored until the tumbling operation was complete; then it was opened and the barrel rotated to dump the processed castings in the skid on the floor. After it was emptied, they would again rotate the barrel and open the tail gate of the skid to automatically load the barrel. The operation worked very satisfactorily and it was really surprising to see how much hand labor was eliminated by this mechanical means of handling. This was a foundry that had paid a great deal of attention to their major processes, but for quite a long time neglected some of the ragged edges that apparently could not be worked out for their continuous-conveyor scheme.

Discussion–Foundry Costs

CHAIRMAN A. E. HAGEBOECK: In starting this meeting I want to call attention to a matter that came up within the last six or eight months. I have always realized what a bearing the molding labor would have on an estimate of cost, but the tremendous significance of that fact was not called to my attention until recently. We are talking of uniform cost, and I think we are making some very definite progress in that line, but certainly if we are going to build our costs on direct labor, it seems to be within the province of this committee to give some thought as to how we arrive at that direct labor price.

Citing a test case, there is a group of foundries which is working on a fairly uniform cost method, but this particular group never made any effort to go back into the foundry and standardize their price that they paid the molders. Now these particular foundries are of the type where you have long heaps of sand, pour once a day and cut the sand at night. These foundries have been giving more or less thought to the matter of uniform cost, and yet when they came to put their molding prices on a job, the variation was very large. The trial estimating was on a job where the casting weighed four and a third pounds, with four in a mold and using a standard twelve by fourteen flask. There were some twenty-five different foundries in this test and the prices for molding as estimated were reported from four cents a mold to seven cents a mold. Now the job was afterwards actually put in one of the foundries and they had to pay five cents a mold. Our point is that the actual cost of that job in the foundry was twenty dollars a ton after it was put in for production. I say it was twenty dollars a ton for molding labor only; the low man estimated fourteen dollars and the high man estimated twenty-seven dollars. Now those figures are from foundries that think they know their costs, so we can mention this to have you know and realize that we still have a long way to go in this matter of cost education. This next year we are going to have a committee work on this problem of endeavoring to standardize the prices we pay the molder. Certainly there ought to be some basis whereby we can get much closer on our basic figures.

W. J. Corbett has a report to make for the Sub-Committee on Classification of Standard Cost Division Accounts.

Report of Sub-Committee of the A. F. A. Cost Committee

To the Members of the American Foundrymen's Association:

Purpose: This sub-committee was appointed in accordance with the following resolution adopted by the A. F. A. Cost Committee at its meeting in Chicago on June 6, 1927:

"Be it resolved, as the second step towards a uniform method of cost finding in the foundry industry, that a committee be appointed to prepare a standard classification and definition of cost accounts in order that the monthly summary of costs for foundries in the steel, malleable iron, gray iron, and non-ferrous branches be prepared in a uniform manner."

Membership of Sub-Committee: A. E. Hageboeck, Chairman of the A. F. A. Cost Committee, made the following appointments:

W. J. Corbett, Chairman, representing steel foundries.
R. E. Belt, representing malleable iron foundries.
W. D. Goldsmith, representing non-ferrous foundries.
J. L. Carter, representing gray iron foundries.

These appointments were accepted by Messrs. Corbett and Belt, and the sub-committee consists of these two members.

Standard Cost Divisions of a Foundry: The American Foundrymen's Association adopted in 1926 as recommended practice the following definitions for the divisions of a foundry for cost accounting purposes:

1. *Melting Department.* The Melting Department includes the cost of metals and the conversion cost. It controls all labor, including melting, handling, and preparation of scrap, furnace maintenance and repairs connected with the furnaces and with the ladles used for receiving the metal, and the consumption of all materials and supplies used in conjunction therewith. Its province com-

mences with the melting stock and fuel at the storage point and ends at the point where the metal is poured into the ladle at the spout. All items of cost incurred within these limits are charged to the Melting Department.

2. *Molding Department.* The Molding Department controls all the labor of molding, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the materials entering into molding sand mixtures at their point of storage and with the pouring of the metal into the ladle at the spout. Its province ends with the delivery of the castings to the Cleaning Department. All items of cost incurred within these limits are charged to the Molding Department. It is important that the direct molding labor be segregated in a separate account in the Molding Department.
3. *Coremaking Department.* The Coremaking Department controls all the labor of coremaking, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the materials entering into core sand mixtures at their point of storage, and ends with the delivery of the finished cores to the Molding Department. All items of cost incurred within these limits are charged to the Core Department. It is important that the direct coremaking labor be segregated in a separate account in the Core Department.
4. *Cleaning and Finishing Department.* The Cleaning and Finishing Department controls all the labor of cleaning and finishing castings, the maintenance of equipment, and the consumption of all materials and supplies used in conjunction therewith. Its province commences with the receipt of the castings from the Molding Department and ends with the delivery of the castings to the shipping department. All items of cost incurred within these limits are charged to the Cleaning and Finishing Department. The Cleaning and Finishing Department should be subdivided into the following, when the character of

the work warrants such separate departments: Heat Treating Department, Hard Iron Cleaning Department, and Soft Iron Cleaning Department. It is important that the direct cleaning and finishing labor be segregated separately from the other expenses in the Cleaning and Finishing Department.

5. *General Overhead Expense.* The general overhead expense includes all the items of cost and expense not enumerated in the above departments and not chargeable specifically to those departments. Such expenses are: power, light, and heat; general repairs not chargeable direct to the above departments; yard department; shipping; engineering; storekeeping; purchasing; production or order department; accounting department; inspection; safety and welfare; insurance; taxes; depreciation; pattern department expense not charged direct to specific patterns or orders; loss on defective castings after shipment; general office expense; advertising; selling; loss on bad debts; management salaries; officers' salaries; traveling expense; incoming freight not charged to material accounts or to departments in which materials are used; research; reserve for inventory adjustments; other operating reserves of a general nature; etc.

Present Uniform Cost Systems: The steel foundries and the malleable iron foundries through their associations, the Steel Founders' Society of America and the Malleable Iron Research Institute, have been actively engaged for many years in the study of cost finding methods. Uniform cost systems for these two branches of the foundry industry have already been prepared and published. Steel foundries and malleable iron foundries, whether or not members of the associations mentioned above, are urged to adopt and use the uniform cost system for their branch of the industry.

Recommendations: The sub-committee recommends the following:

1. Recognition by the American Foundrymen's Association of the uniform cost system of the Steel Founders' Society of America as standard for all steel foundries. (This

cost system was presented at the A. F. A. convention in Philadelphia in May, 1928.)

2. Recognition by the American Foundrymen's Association of the uniform cost system of the Malleable Iron Research Institute as standard for all malleable iron foundries.
3. A uniform cost system for gray iron foundries to be developed by the new association, the Gray Iron Institute, being organized.
4. A committee of representatives of non-ferrous foundries to be organized for the purpose of developing a uniform cost system for this branch of the industry.

Conclusion: The sub-committee believes it to be inadvisable for the American Foundrymen's Association to deal with the details of cost accounting practice, as these can best be handled by the individual branches of the foundry industry as recommended in the foregoing. Therefore, it is the opinion of the sub-committee that the A. F. A. should confine its activities to educational work along the lines of cost accounting and the application of such to merchandising and manufacturing.

Respectfully submitted,

R. E. Belt,
W. J. Corbett.

The report was presented and accepted by the meeting for forwarding to the Board of Directors for approval of the committee'e recommendations.

The paper on Cost Finding Practice for Steel Foundries was then presented by W. J. Corbett. This paper will be found beginning on page 25.

Discussion—Cost System for Steel Foundries

W. J. Corbett: In presenting this cost system for steel foundries, on behalf of the Steel Founders' Society of America, I shall not attempt to deal with all the details in the paper, which probably need no further explanation and which might cause you to be bored if required to listen to them. Therefore, my brief remarks will be restricted to the treatment of the subject in a very general manner.

The uses of a cost system and the advantages of a uniform cost system by members of an industry have been set forth in the paper containing the cost system. Perhaps one of the most important uses of a cost system at this time and in the future, is the last one given, namely, to furnish data for intelligent merchandising. The others, of course, are

also very important, but I am placing special emphasis on the one just mentioned as it probably needs greater consideration by foundrymen. All of us know how difficult it is to reduce by $5.00 a ton the cost of making castings and what great effort is required. We also know how easy it is in competition to reduce the selling price of castings $20.00 a ton, and yet give less consideration to its effect on the profits of the business than to an increase in costs of only a small fraction of this amount. Hence, it appears necessary for the foundries to make as much use of costs, if not more use, in selling their castings as in making them. The success of the business depends on using costs for both purposes.

In a highly competitive industry which has too much capacity, such as the steel casting industry, and the iron casting industry as well, it is important that a cost system be used for determining the cost of individual castings in order to know whether or not the castings are sold at a loss. There are some foundries that disregard costs when selling their services, or probably a better expression might be "when taking orders." Their merchandising is conducted by chance and by assuming that if another foundry can sell castings from a certain pattern at a certain price, they can do likewise. Such an assumption may lead one foundry ignorant of its costs to merely follow other foundries equally ignorant of whether or not a severe loss will occur by taking an order. This is unintelligent merchandising which is detrimental to an industry.

Reference is made in the cost system to the use of average or normal costs. This is a very important part of any system for determining the costs of individual castings. With the hope that business is always going to be improving, some foundries fail to base their cost determinations on normal or average operations. Consequently, the overhead rates which they use for calculating the costs of castings made from specific patterns are too low, due to their being taken from costs covering good business conditions only. As a result of this practice of determining the costs of individual castings on the basis of the volume of business the foundry can produce or expects to produce, such costs are lower than they should be.

Since the foundry business is always fluctuating, an important consideration is the use of costs representing average operating conditions when overhead rates are established. The fact that a foundry may operate for one month or for a period of several months at a rate of capacity somewhere near its maximum, does not justify the use of costs obtained during such a period for establishing selling prices. The cost of making a specific casting is usually no greater when the foundry is operating at 50 per cent of its capacity than when it is operating at 100 per cent of capacity, although, of course, the total average cost per ton of all castings made during these two different conditions of business varies, due to certain items of expense remaining fixed in amount regardless of tonnage produced.

This brings up the question of taking orders at low prices to absorb the overhead expense. Theoretically this questionable competitive policy might seem justifiable, but when put into practice it is only helpful in

demoralizing the market conditions in an industry such as the foundry industry. Castings are purchased only as the need for them arises, and low prices—prices at or below the normal cost of production and which do not include a fair profit—do not stimulate buying of castings. Therefore, when a foundry deliberately practices the taking of orders at these low prices and believes that by so doing part of the overhead expense is absorbed, it must be prepared to withstand retaliation by its competitors who are not willing to stand by indefinitely and lose their rightful share of the existing business.

Normal operations in the steel casting industry represent 60 per cent of capacity, and when operating at this rate the industry should earn normal profits. Perhaps in many instances the profits that ought to be considered normal may be earned only when the rate of operations is very much higher than the normal rate. If each competitor in the industry would adjust his cost determinations for making selling prices to his normal or average rate of operations, competition would become more intelligent and reasonable. Each one would become satisfied with his share of the available business and would not be so apt to take additional business at ruinous prices.

Since it is obvious that the use of a cost system for determining the normal cost of making specific castings should have a beneficial effect on market conditions, the question arises concerning the amount of profit to be added to such costs in order to establish fair prices. There may be an inclination on the part of some foundries to add to their costs an amount of profit insufficient to provide a factor of safety which is necessary to take care of probable errors in their estimates. It would be futile to claim that estimated costs are 100 per cent accurate. In some cases they may be decidedly inaccurate due to errors in weights, direct labor costs, defective castings, etc. Since estimated costs are used for establishing selling prices, it is essential that errors in judgment when estimates are made be provided for by adding a percentage of profit great enough to safeguard the foundry from possible losses.

Fred Erb: This is a very commendable paper, and the work of the steel foundrymen is also very commendable and should lend encouragement to the gray iron foundrymen to try to develop something, that approaches this system that has been developed by the steel foundrymen, for gray iron users.

J. L. Carter: The main object of running a foundry is to make a profit, and the main objects of a cost system, I might say, are two; one is to determine the selling price and the other is to control your production. I am only thinking now of the use you make of it to set your prices. Your prices are not set on your cost alone; everybody knows that, and if the ultimate effect of any meeting like this is just to impress upon foundrymen the necessity for getting an accurate cost system, I do not think it has gone far enough. After you have obtained your cost figures, when you try and set your prices you come up against competition, and that is setting

more prices today than costs. My belief is that the essential thing about cost in the foundry business is to establish more uniformity in the cost systems used by the different foundries that are quoting on work, and I think the most important thing any of you can do is to get together with some of the other foundries in your neighborhood and try to arrange some way whereby you all figure your costs the same way. It has been done. It is being done by an increasing number of groups, and I think the main thing needed is to get the foundries together in local groups, where you can all sit down and figure your costs on the same uniform system. If you do that, you have some way of getting away from the schedule fallacy which is being forced on the foundry largely by the customer and also by some of the old line foundrymen who do not realize what a poor policy it is. But you cannot get away from it unless you educate the foundrymen to get away from it, and educate the customers also, and that you can only do by joint action in all the foundries in your neighborhood.

If you decide to get away from the schedule system, but your competitor insists on quoting by it, you will have to do the same thing; so I advise you to go home and get next to your nearest competitor, take him out and play golf with him, and then sit down and decide that you are going to figure your costs by the same method. We hope that some day the Gray Iron Institute will develop a cost system for gray iron foundries which can be available for any group that wants to use it, and some day we will all be figuring costs on the same basis.

A. C. Porter: Some foundries, I believe, apply their overhead to their molten metal, some to the pound per casting, and some to the dollar for labor. In applying it to the dollar for labor, I would like to ask if any of the foundrymen here have a definite ratio of applying the overhead as pertaining to hand molding and machine molding? By that I mean is there a ratio or a differential between a man molding job and a machine molding job, and is it a standard differential or does each particular foundry have one of their own, or is there some place where we can get that information?

Chairman A. E. Hageboeck: Your question, as I take it, is if you are figuring that you have, we will say, a hundred per cent overhead in a certain department operating hand molding, what should your overhead be if you had that same job on the molding machine?

W. J. Corbett: There is nothing definite established and I cannot make a specific answer to that question. I think that depends on the local conditions, and on the proportion of machine work, to the total amount of work done in the molding department, and that varies in different foundries. It might even be questionable if there should be any differentiation. I think it was mentioned that there is nothing in this paper about general overhead. You will find that described fully on page 55. Some of it is applied on direct labor and some of it on weight.

Chairman A. E. Hageboeck: Mr. Harper, have you any figure where you make certain jobs by hand molding, and then in another department

make them on machines? What is the relation of those two overheads? Is one a third more than the other, or half, or twice as much?

J. F. HARPER: That is a difficult question to answer. The floor space area, together with the percentage of the total labor, should be figured into that. In other words, your general overhead should be apportioned on the amount of work coming out of that part of the foundry, and the capital investment of all those things that go into general overhead will be different in the machine end of the foundry than in the hand molding end, and the overhead would naturally be higher in the machine end. I have no definite figures that would be applicable.

CHAIRMAN A. E. HAGEBOECK: In other words, if we had this floor in hand molding and put a lot of molding machines in here, and got more tonnage on the same floor, your percentage of overhead would go up very materially.

Mr. Corbett, the other question brought up was as to how to apply the overhead, on tonnage or direct labor?

W. J. CORBETT: You will find that described fully, I believe, as fully as we were able to describe it, in this paper on page 55, where we divide the general overhead expense, meaning that which is not applicable to any one department, and apply part of it on the total direct labor and part on tonnage. I believe that in the average foundry this would amount to about fifty per cent on the total direct labor and about fifty per cent on tonnage.

F. ERB: Most of us are frank to admit we do not want to get costs with too great an accuracy, because in the attempt to get accuracy, we are inaccurate at the best and we do not want to overlook the fact that we are making our jobs on a floor where our direct labor is much higher and naturally the overhead is increased on that job in actual dollars by being figured as a percentage on the direct labor and against the percentage on direct labor to be applied on the machine floor.

DISCUSSION—THE SCHEDULE FALLACY

Chairman Hageboeck then introduced J. J. Ewens, of the Geo. H. Smith Steel Foundry of Milwaukee, who presented the paper, "The Schedule Fallacy," which is printed beginning on page 63.

S. R. ROBINSON: Mr. Ewens are you now using this system and with what success is it being accepted by the consumer? What is the attitude of the consumer?

J. J. EWENS: We are using the individual price basis on most of our work today; I should say on seventy per cent of it.

CHAIRMAN A. E. HAGEBOECK: Have you met with any opposition?

J. J. EWENS: Yes, we have in some cases. We have customers that we still sell on schedule.

CHAIRMAN A. E. HAGEBOECK: I would like to have some one else answer the question, what resistance have you found when attempting to apply a price, either per pound or per casting?

W. J. CORBETT: Probably the principle of a lump price per casting applies particularly to small castings. It would be rather difficult to apply it to large steel castings; that is, to sell them at a certain number of dollars per casting. They are usually sold at a certain number of cents per pound.

CHAIRMAN A. E. HAGEBOECK: But the price in on an individual casting, is it not?

W. J. CORBETT: In competition, yes. As a result of inquiries received by foundries, prices are usually or should be based on estimated costs per pound for castings from each pattern.

CHAIRMAN A. E. HAGEBOECK: Because you want to take care of variations that occur in weights and costs of making castings of different designs?

MEMBER: That is becoming the general practice of the Steel Founders' Society.

CHAIRMAN A. E. HAGEBOECK: Are the steel foundries looking forward an individual price per casting?

W. J. CORBETT: In quoting prices on miscellaneous castings, yes. There are many foundries that use the system of individual price per pound for each casting, and in addition to that, they have some schedules with certain customers as Mr. Ewens in his paper says his company has.

E. W. JONES: I have been for several years selling my castings on an individual price. Molding and core making is what governs our price. All my work is piece work, both in the molding and core making departments. Now on small castings or small orders, say one or two castings, I will add an extra overhead cost for handling that order which may run double my profit.

A. C. PORTER: In the recommended method of selling castings by the piece, do you mean to sell, for instance, a hundred pound casting that you want to sell around eight cents a pound, at eight dollars per casting to the customer, or do you mean to figure your cost per individual casting and sell it on a pound basis for that particular casting? We have tried for five years, out in our country, to convince our customers that it is to their advantage to buy on a piece basis, so many dollars per casting, not so much per pound for that casting. Frankly we did not get to first base. In the first place, we did not want to go to the trouble of checking up all their patterns and what a casting should weigh, what it did weigh, and rearranging their price list. Consequently we had to go to the plan of taking each individual casting, figuring a cost on a per piece basis, but selling it on a pound basis for that particular casting.

CHAIRMAN A. E. HAGEBOECK: That is all right; you accomplished the same thing.

A. C. PORTER: Is that the recommendation that the author is putting through, to sell it on a piece basis or take it on a weight basis?

J. J. EWENS: It amounts to the same thing, except that if you sell on a piece basis alone, you are putting the penalty on the foundry of maintain-

ing weights. We are doing both at the same time; we are selling at eight dollars a piece or at eight cents a pound. We would prefer to sell at the pound price per piece rather than the flat dollar charge.

MEMBER: We have induced quite a few of our accounts in the gray iron industry to go to a piece price basis, so much per hundred or per thousand pieces, and we have found it to work very well. It has eliminated the old idea of the purchasing agent saying, "How much a pound?" It was a matter of comparison; and today, on a piece price basis, we quote so much per hundred pieces and other foundries are called in and quote on the same basis, and prices are compared in that manner. It has worked to decided advantage in our district.

We show them that it eliminates a great deal of work in their cost; if they know the price per piece, it is not necessary to get the average weight and multiply it by the pound price. We at first went over our old shipping slips and took an average weight. In reality, the price of the casting showed a slight variation in the gray iron industry, of half a pound or even a pound on a casting, but that does not amount to a great deal with the low cost of iron today.

CHAIRMAN A. E. HAGEBOECK: I know that in our own case I have been called upon to make a quotation and the buyer insisted on a pound price. We figured the entire job on a per casting basis; in his case we worked it out on a per casting per pound basis and after we got all through, we got the grand average on that particular order. Then if we got the order, we still insisted on our individual price. To my mind it has every advantage, because he may take some of those patterns and give them to somebody else, and if you have it on a per casting basis, he can do that and it does not hurt you. He may change the design, which does happen every day, and when that happens you do not care; one casting goes out and it is a question of refiguring that one job.

I think many foundries, at the end of the year, lose a lot of money because they do not watch their prices, because their casting users have changed their designs and method of ordering, so that at the end of the season you have not got the orders you thought you had at all; you did not get the orders you bid on, and an individual price per casting, to my mind, will protect you much better than an average for a whole lot.

W. JACOBI* (WRITTEN DISCUSSION): There is one criticism to be offered on Mr. Ewens' paper and that is that he did not make his objective emphatic enough. For the good of the Industry the attack on the price schedule must be loaded with high explosives. No one can do this more effectively than this Association by resolving unanimously to abolish the practice and do it at this meeting.

How many of the foundries that have liquidated or gone out of business within recent years owe their downfall to the price schedule can only be surmised. It is safe to say that this famous schedule has never earned an honest dollar. All it has done is to nurture unscrupulous

*Keokuk Steel Castings Company, Keokuk, Iowa.

destructive competition and its arbitrariness is enough ground to declare it unfit for good business.

The working up of piece prices on the merits of each kind and size of casting is not a difficult matter as has often been pointed out and on this there is nothing to be added to Mr. Ewens' paper even though necessarily each foundry must find the method best suited for its needs.

There is however another very legitimate item of cost which is often thrown in the bargain or deliberately grabbed, arising from the responsibility assumed by or imposed upon the foundry to cover the soundness and perfection of the castings made or to be made, and that is, a service or development charge for perfecting patterns or even modifying the design of castings by the foundry to secure the quality and lowest cost of the product desired. More than that, and this applies to the cast steel foundry in particular, we can not lose sight of the fact that in the production of castings we are dealing intimately with the structure of materials whose properties are out of the scope of common shop practice and whose application demands a high order of engineering or scientific training which usually is far from the understanding of the everyday designer who usually has not passed the stage of a mere draftsman. We mean to say that the foundryman alert and alive to the requirements of today can not nor should be made to assume the responsibility for perfect castings unless he had had a voice in the design of the castings and of the patterns required therefor. This procedure indeed is more than a convenience, it is a real service which will result in saving of money to the buyer and must be paid for either as an independent fixed charge or prorated into the castings to be made.

It is not a case of draft, shrinkage allowance, locating and proportioning heads and gates, best type of pattern, flask equipment, and what not—to secure continuously and unfailingly perfect castings intended for particular service; it is distinctly a case of selecting mass proportions properly interrelated to the nature of the metals used and their treatment and this sort of skill is rightfully within the domain of the foundry's activities other than making molds and pouring metal. No rules can safely be laid down for any one else to follow.

There is too much blaming the foundry for defects arising from poorly designed castings. Such practice, often indulged in even by parties who know better, is nothing short of a copartner of the price schedule and with it should be abolished.

We have today a very important line of castings which are of particular interest to the steel foundries where they properly belong and that is the line of pressure pipe fittings for which definite standard dimensions have been set. Any one who has made these castings and honest manufacturers of the finished fittings are fully acquainted and recognize the dangerous hazard accompanying the disproportion existing between the massiveness of the flanges and that of the body of the casting, also between heavy lugs or bosses and adjacent thin walls. All precautions

notwithstanding we always dread the unexpected and uncertain shrink cavities, and other unnecessary defects to say nothing of the makeshifts resorted to in an effort to eliminate or correct those defects. In Europe where exacting research underlies the design of all mechanical parts, the proportions between flanges and the body of the fittings are better balanced and more in keeping with the inherent tendencies or laws of metal structures, and as a result less dread prevails on the uncontrollable defects which for us constitute a menace.

Investigation of one form or another reveals that the judgment for the unduly heavy flanges in our pipe fittings is based on the propensity or fear on the part of pipe fitters of distorted flanges when bolting. Consequently the flanges are made "foolishly strong." Obviously there is no sound premise on which to support this "foolishly strong" practice which should have been overcome by proper use of wrenches and not by penalizing the foundry for unnecessary resulting defects.

In our opinion the A. F. A. should nominate a committee to confer with the A. S. M. E. Standards Code Committee and through the means of an open discussion assist in the determination of proper rules and dimensions on cast metal pressure fittings.

Heretofore it has been a more or less accepted understanding that foundries, not unlike other producers of raw or semi-finished materials are subordinate to the industries they supply. Commercially they possibly are, but in the manufacture of quality of product they are on an equal plane and possibly the situation is very much the other way about.

Briefly, the field of the foundry is greater today than ever before but its bountifulness and success depend entirely on sound business principles on which the industry is conducted accounting one by one all the items of service it renders.

Discussion–Apprentice Training

E. S. Sparks presided as chairman of Session No. 13, on Apprentice Training. The papers which were discussed as a group were as follows:

Chairman E. S. Sparks: The matter that we are to discuss this morning is not new like "mass production" and labor turnover"; apprenticeship is not new. I have found from recent reading on the subject that it arose sometime back in the Middle Ages, about a thousand years ago. In 1562 there was enacted in England a law that no person should practice an art, trade or mystery, except after having served an indentured apprenticeship of seven years. Approximately 250 years later—in 1814—there was another law enacted which gave anyone the privilege to practice an art without serving an apprenticeship. This first law gave a monopoly to the craftsmen of that day and you in the foundry business know that that same monopoly has to a certain extent prevailed largely through the influence of labor organizations, although the labor organizations have not had rules that were as stringent in their attempts to exercise that monopoly as the layman quite ordinarily supposes. Perhaps you are aware that the constitutions of many of the labor unions, particularly the molders union, allow one apprentice to five journeymen.

Investigations in this area and others lead to the conviction that the lack of foundry apprenticeship has not been so much due to restrictions of labor unions as to the neglect of foundrymen. There has been in the last ten years notably increased attention directed toward apprenticeship. I think we should be more interested in the qualitative, rather than the quantitative side of this subject which is to be presented today. We are going to deal with both phases but as we are progressing with our program and the various standards are being set up, I think you will see that it is the qualitative side of apprenticeship with which we are largely concerned.

The first speaker, Charles F. Bauder, who is Director of Industrial Arts of the Philadelphia Public Schools, will cover in a general way the apprentice situation in Philadelphia, Pittsburgh, Milwaukee and Detroit.

Dean C. B. Connelley: I don't know that there is a person here who feels as gratified with the progress that has been made in the last 10 years in the foundry so far as apprenticeship is concerned as I.

Here in Pennsylvania when we were working on the laws of Compensation we found that some industries were considered so hazardous that it was found inadvisable to have persons employed until they were mature and developed and the law placed the age at eighteen. I would be very sorry, indeed, if any foundry, machine works, electrical establishments or any large manufacturing plants would hesitate for a moment to ignore this law and not take a boy until he is eighteen, because between the ages of sixteen and eighteen if he is not steadily employed he lacks ambition and in a very little while becomes hard to control and that means he is not a useful citizen. The law was meant for only a very few industries and did not mean what many who are opposed to apprentice training are trying to force on the manufacturers.

Take the condition in the plumbing trade. The high wages that apprentices are receiving are bad for the young men in the work. We have learned that the apprentices in the last year get $45.00 a week where the journeymen get $60.00 per week. Far be it from me to not advocate a wage commensurate with ability, but I feel we are making a mistake and I trust you will think this matter over as well.

Another point I wish to mention is to try to get the big man in the plant interested so that he will be able to appreciate the value of training apprentices. It is hard to convince many men of higher position in some of our corporations as it is hard to try to convince some of our men on the school boards of different parts of the United States, the fact that a well trained apprentice is an asset to the industry as well as to the community.

A quarter of a century ago, very few schools in this country were furnishing opportunity for trade and industrial education. Andrew Carnegie saw the necessity for it and established a school for apprentices and journeymen, later a school here and there was started for the training of trades. Then the Society for the Promotion of Industrial Education was organized and for more than ten years fought for what is known as the Smith-Hughes Bill. Then came the progressive boards of education of our country and then the American Federation of Labor, all realizing that something must be done to change the order of their present condition and try and get to a place where the apprentice could be trained "as of yore." Many schools that started to train apprentices such as my own, the Carnegie Institute of Technology, left that field for something else and turned to higher education. The demand, however, became so great for

the apprentice training that the Public Schools were forced to take up the work. That led to organizations such as the American Foundrymen's Association taking up this work through a committee and through these efforts most every large foundry center is having training either through the corporation or the public.

Mr. Hartley who, for a number of years, has been Educational Director of the National Founders' Association has a scheme for the advancement of foundry apprenticeship work and the science of the foundry industry. When he gets the scheme into operation, I am sure it will add greatly to the education of the man in the foundry, both for the Apprentice and the men who have extreme practical experience. I trust that Mr. Hartley will say a word or two about it.

L. A. HARTLEY: I believe that there is one thing the foundry industry needs more than any other at this particular time. I refer to foundry fellowships in engineering schools and technical institutes. We need a channel through which there may be a continual development of practical training and technical information in an unbroken line from apprenticeship to research in applied science of foundry operation.

During the past few months, I have been asking foundrymen the following questions: First, how is your business? Second, how much are you doing in the way of technical research? Third, how much are you doing in the way of apprentice development in your plant? I have found without exception that the foundries doing a pretty fair business are the foundries which are doing those things; and the foundries which are not doing this work report that "business is rotten." One of the busiest foundries in the city of Philadelphia is the Cresson-Morris Foundry. It is running day and night shifts. This foundry reports also more apprentices than any other Philadelphia foundry, and this particular foundry in addition is doing considerable research. This is merely given as an example of how apprentice training and research go hand in hand and pay dividends. Other foundries have similar experiences.

I believe there is now room in this country for about five fellowships in which graduates of technical courses will be supported by foundrymen having special problems, the graduate to devote a year or more to research and investigation with a view to solving the problem to which he is assigned. The young man could thus continue his education and specialize on some certain foundry problem. I believe that this would be a great help in solving foundry problems, and apprenticeship would be a direct aid to such Fellowships through the functioning of special apprenticeships in plants interested in this method of getting at problems.

The plumbers and manufacturers of plumbers' supplies have provided two hundred thousand dollars the income from which is to support a Chair in plumbing. Its purpose is research work for the plumbing industry. This is certainly worth while.

Graduate students who are doing special research may be maintained for from $1,200.00 to $1,500.00 a year. If research problems were properly

selected and the right young men selected for fellowships, this type of research would pay big dividends. A foundry having a particular problem could thus obtain the special assistance of a graduate student who possesses the fundamental information necessary to research, has the equipment of the college at hand, and is in a position to receive the counsel of the members of the faculty.

We must find new uses for cast iron, new uses for steel, and new uses for malleable iron; and one of the most economical ways to do this is to promote all kinds of research work and investigation through apprenticeship, fellowships, and later, possibly, a foundry chair.

CHAIRMAN E. S. SPARKS: If you want to make converts, you have to get the sinners into the congregation. I have the feeling that almost everyone here is a convert to the desirability of an apprenticeship system and I think you must take it upon yourselves to go forth and preach the gospel to those who do not subscribe to it. Your neighborhood is made by your neighbors, and industrial conditions are made by your fellow manufacturers. You can exert a wholesome influence upon them and awaken them from their apathy on this matter. You must get them to cooperate if this problem is to be solved. I hear that employment conditions in many other areas are like those existing in Philadelphia; that while a lot is being said about unemployment, a real scarcity of skilled labor exists. The situation emphasizes the necessity of more and better industrial training if we are going to have sufficient skilled labor for the future.

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